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THE RELATION OF AGRICULTURAL SERVICES TO CHANGING CONDITIONS[1]

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Mr. President and gentlemen:

I am going to talk to you tonight about agricultural conditions in Great Britain as they affect the Agricultural Adviser, the man who, in our country, is known as the County Organiser; and I will also touch on conditions as they affect the Canadian agriculturist. In order, however, to understand present conditions in British agriculture, or indeed in world agriculture, it is necessary to know something of how they arose. For in agriculture, as indeed in most other human activities, the best key to the present is the history of the past.

For many years, and right up to comparatively recent times, agriculture had developed in the direction of enabling each region, sometimes each village, to be self-supporting. Transport was practically non-existent for bulky agricultural products; whatever the local farmers could not produce people had to go without. From time immemorial there had of course been transport for such costly things as metals, precious stones and luxury articles, but transport in food is a recent development. The old system of agriculture, both in Great Britain and also in Canada—the old French system—was, therefore, necessarily one of mixed farming in which each farm produced a certain amount of live stock, of cereals and other food stuffs for human beings and for animals, as well as flax, wool and hides to make clothing and other necessary articles for human use; even oil was often produced on the farm from colza and rape.

Then came in bewildering succession the marvellous discoveries of the 19th Century which made it one of the most brilliant epochs in human history: discoveries in science which revealed for the first time to the astonished gaze of mankind something of the infinite wonder and complexity of the world in which we live, and yet of the underlying orderliness and regularity which the scientists of those days expressed by strikingly simple generalizations—now known, however, to be only approximations to the truth, the generalizations as we know them being much more complex. There were equally striking advances in practice, which resulted from applying the new scientific knowledge to the problems of everyday life. One of the most remarkable of these practical achievements had been the discovery of artificial fertilizers, made at Rothamsted about 90 years ago but based on the earlier work of the plant physiologists and greatly influenced by Liebig, of which we are naturally proud. The first Rothamsted field experiments showed these self-supporting farmers how to increase their yields considerably and without

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difficulty. Prior to this discovery the average yields of wheat in Great Britain, though not known precisely, had been somewhere about 20 bushels to the acre. Within about twenty years of the discovery the yields had been pushed up to about 30 bushels, and other crop yields had similarly increased. Along with the development of the artificial fertilizer industry in Great Britain came other improvements in agriculture, and the net result was a considerable increase in yield, and, perhaps even more important, in certainty of yield. It was the first time that science had been applied to agriculture and the result was a great success. It did not, however, alter the system; this still remained general and self-sufficient.

Later on, however, there came those engineering developments of railways and steamships that opened up these lands of Canada and the United States, and made it easy to transport commodities from here to Great Britain. The first commodity to be sent over in any quantity was wheat. It was grown here and in the United States more cheaply than in England and consequently was put on to our markets at prices with which our farmers could not compete. Many of them, therefore, had to give up wheat growing as a principal occupation; they retained the crop, of course, but it became a subsidiary product in our agriculture, and for many farmers this is what it still remains: some grow it to feed their poultry, others for the sake of the straw. Several of our agricultural systems require a certain amount of straw, and wheat is a very convenient source of supply. Other farmers grow wheat after expensive crops, like potatoes and mangolds which are fertilized heavily; they do not like growing these crops on the same ground year after year because of the danger of disease. After one crop has been taken off, some other is sown which is so different that it cannot carry the same diseases, and wheat is one of the most convenient for this purpose. Following as it does a heavily fertilized crop it needs no additional fertilizer and but little cultivation; good yields of 40, 50 or even 60 bushels per acre are, therefore, obtained easily and cheaply and so we have been able to continue wheat growing in competition with you. But it is essentially a secondary product.

This bringing of wheat from Canada and the United States on to our market at prices below which our farmers could grow it was the first break in our ancient self-sufficient system of agriculture. In general, however, our political leaders did not worry very much about that. They were greatly impressed by the possibilities that these new developments of science and transportation were opening up. The world seemed to be shrinking very much in those days of seventy or eighty years ago, and there arose a great school of liberal thinkers in our country, who worked for an ideal that Tennyson expressed in glowing words, "the Parliament of man, the Federation of the world". They saw the ancient barriers of time and distance breaking down and the whole human race becoming one family. Their ideal was that each region should produce the things for which it was best suited, and that the nations of the globe should work together in peace and friendship, each one contributing what it best could to the common stock which they called the World Market, and all exchanging their commodities without any artificial restrictions. It was the great doctrine of Free Trade. There were to be no barriers, no hindrances whatever to the free exchange of the goods which each nation could produce. Western Canada for instance, could produce our wheat; Eastern Canada could supply us with apples, dairy

products, and bacon; Australia could send wool and more wheat; New Zealand, lamb and dairy products; and South Africa, certain fruits. All these, and the products from other parts of the world were to be received by us in exchange for coal, iron and manufactured articles which we could send out. That quite naturally led to the idea of specialization; each region, instead of being self-supporting, was now to specialize in those things which it could produce best.

It was not, however, these doctrinaire considerations, but sheer necessity that drove our farmers to specialize according to their local conditions. In the eastern parts of England where we have a low rainfall, some 24 inches annually fairly evenly distributed, much of the land remained arable and was, and still is, used to produce cereals and other arable crops. In the western parts of England where the rainfall is 30 inches and more, up to 70, 90 or even 100 inches, grass is the appropriate crop, and so this region produces livestock and its various products, milk, dairy products and young animals for sale to arable farmers. Other specialized regions also developed, devoted to fruit, market gardening, potato and vegetable production, dairy husbandry and other activities. One great advantage of this specialization was that it enabled our farmers to take full advantage of modern developments in agricultural science. They became experts, seeking improvements all the time in order to raise the yield or enhance the quality of their products or lower the cost of production, and they could appreciate the results of agricultural experiments bearing on their problems. They could recognize also the need for them, and it cannot be too strongly impressed upon the political leaders in any community at the present time that the more agriculture becomes specialized the greater is the need for scientific work. The general farmer can afford to make a few mistakes; if he loses on one crop he always has three or four other commodities that may bring him out all right. But the specializing farmer cannot afford to take any chances; he has staked everything on his specialized products, and he must have all the help the man of science can give him in order to avoid the possibility that anything should go wrong. Along with specialization, therefore, comes the need for a strong agricultural research advisory service to discover underlying principles and new facts, then to apply this knowledge to farm problems, and finally to pass the information on to the farmer, interpreting it in language which he can understand and making experiments on ordinary commercial farms to find out just how the new knowledge can best be used in practice.

A further advantage of this specialization is that it leads to improved conditions for the farmer, higher and more certain yields, lower costs of production, and, therefore, greater prosperity for him and for the farm workers. The old system of self-sufficiency often meant a low standard of living such as is still found among the peasants of many parts of Europe, especially in Eastern Europe. It is not uncommon there for peasants to work and work well for a very small return; probably its cash value would be little more than five cents per hour. That is not the kind of remuneration that appeals to our workers, or to yours; but these peasant people, these small general farmers who lack the aid given by science, are not yet in a position to obtain more.

That, then, was the great agricultural movement up to the time of the war; a change over from general farming to specialized farming, and it came about as the result of the development of transport. The first product to suffer had been wheat, but gradually other products came into our markets as well; before long no agricultural product was safe from competition. To meet this our farmers became more specialized, thereby calling forth the need for the fuller development of agricultural science.

Then came the war with its complete dislocation of all ordinary channels and services of trade, its breakup of the fine adjustment between supply and demand. Of course that seriously affected the specialization arrangements because it meant that commodities no longer flowed easily and naturally from one country to another: hindrances of one kind and another grew up in the form of tariffs, exchange difficulties, and monetary restrictions, but there was an even greater effect: during the war inventors had been busy and they had developed a new invention, which, while certainly known before the war had not figured very largely in our civilization—the internal combustion engine. This was the child of science: it was the direct outcome of purely chemical work done on explosions in gases, very interesting as chemistry but apparently of no practical value. Then followed much chemical and metallurgical work on the properties of new alloys: again interesting but much of it apparently of academic interest only. But suddenly, the practical application came when engineers showed that these explosions, if carried out in cylinders, could be made to drive pistons, and the new alloys furnished metals of sufficient lightness and strength to enable them to construct engines that would work. So the internal combustion engine developed, and in due course was introduced into agriculture. That had the immediate effect of lightening the work of the farm and speeding up the operations, but later on, with the post-war improvements, it went far beyond what it had ever done before, and began displacing men from the land. You all know how far this has gone already, but no one knows how much further it may yet go. I was looking up the records of one of our wheat fields just before I left for Canada. In the year 1852 we had required 65 men to harvest that field in one day. Last year it was harvested with four men, using, of course, a tractor. And that process of displacing men has already gone far in England, not only in our agriculture, but in our other industries also, and it still continues. This displacement of the man from the land, the factory, and the office is creating a great army of unemployed people who are no longer needed for the only job they know how to do, and who see no prospect of ever being wanted again. One farm of 900 acres in England that has recently been mechanized, formerly employed 40 men and afterwards employed only 4, the other 36 having been disbanded. I asked what had become of them and was informed that only 10 had then found other work: most of the rest were on relief works, being subsidized heavily by the community, or were unemployed. If we try to work out a balance sheet to see how much the community has gained by the replacement it really doesn't appear to be much, because by the time the displaced men and their families have been maintained the community has spent a good deal that would have been saved had these men remained on the farm and produced food at rather higher cost than the machine could do it.

That is one of the great problems confronting us to-day. We are bound to go on developing agricultural science and practice, and engineering science and practice, and yet the more they are developed the worse this problem of displaced men is likely to become.

A third great factor that has profoundly affected British agriculture is the wave of nationalism that has spread over the civilized world since the war. Every country now aims at being an independent unit, not only the large ones, but also the Eastern European countries liberated as a result of the war from the great Empires into which they had been constrained: Poland, Czecko-Slovakia, Lithuania, Latvia, Estonia, Jugo-Slavia and others. For the first time they are feeling themselves free, independent units—like boys just liberated from school. For the first time for many years they are assured of their independence, and of their opportunity to develop themselves in their own way. The older countries are inspired by the same desire to be self-contained and independent of the rest of the world, to produce all they want, importing nothing but only exporting. And, although it passes the wit of man to discover how a country that makes importation difficult can ever hope to make exportation easy, most countries are now trying it. The favourite method is to set up high tariff walls so as to shut out the products of other nations and give their own nationals a chance to develop, an ideal with which one cannot quarrel. Big nations can indisputably do what they like within their borders, and it is equally certain that the small nations have a perfect right to live and to develop themselves in the way they consider best. Some of them we know are highly gifted people who can contribute greatly to the richness of life in our civilisation. And so, although one regrets the disadvantages of this new birth of national spirit—the birth-pains, perhaps one might call them—and the suffering that has been brought about by all these restrictions on trade and movements of human beings, nevertheless we cannot quarrel with the underlying idea, nor deny these nations their right to independent development on whatever lines appeal most to them. A very difficult situation resulted from these new nationistic developments, and particularly from the attempts made by each country to export, but not to import. There were so many exporters, and so few importers, that prices fell very much, and many governments helped their exporters in one way or another so that they could send out goods at less than the cost of production. That affected us very much, because, as ours was practically the only free market in Europe, we had things dumped on to it at prices with which our farmers could not possibly compete. Several factors enabled the Continental farmers to beat ours in low costs of production. Many of the Continental farmers can obtain good labour very cheaply. But our farmers are not allowed to employ labour at low wages. They are subject to a minimum wage rate, fixed by law, of thirty shillings a week for adult agricultural labour. This, of course, fixes a minimum cost of production below which the English farmer can not compete. Our farmers also suffered from another kind of competition. In a good many parts of the world, and in some parts of the Empire, the home market is protected, so that farmers can sell their products at a price sufficient to cover the cost of production of their whole output: they can then put their excess produce on the world market at any price it will fetch. Some countries go further and subsidize exports.

Transport had developed so remarkably well that distance no longer protects the farmer. Liquid milk, it is true, cannot yet be carried far, and it is indeed the only agricultural product for which our farmers have any natural protection. But butter can be brought from New Zealand in five weeks, and although it has to cross the equator, transport is so perfect that it arrives in splendid condition on our tables. Lamb comes in great quantities from New Zealand and Australia, and so efficient are the transport arrangements that when it is cooked an ordinary person can hardly distinguish it from fresh English lamb. Plums, peaches and apricots come all the way from South Africa and suffer no loss of quality; the plums arrive with the bloom on them, as fresh as if they had just been taken from the tree. Our farmers might have competed against these various products if wages and other conditions were the same all over the world; but they cannot unaided compete against superior natural conditions, lower rates of wage, or subsidized exports, nor can they compete against men guaranteed a home market and sending only excess produce on to our market at any price it will fetch. All our agricultural products were affected, and we felt that there was not a single thing left which the English farmer could produce at prices that would even bring back the cost of production, let alone any profit.

Two or three ways of meeting the situation were tried. It was soon recognised that the problem could not be solved entirely by scientific workers. It was no use for us to discover new and cheaper ways of production, because, of course, the information is at once given out to the whole world, and other countries can proceed to put it into practice so far as they think it helpful to them. Science proudly and indefatigably boasts that it knows no boundaries and will acknowledge no nationalism or indeed any other political dictation; by a fine tradition it generously gives its results freely to all for use or application as they may think fit. Rothamsted has always been open to any scientific worker from any part of the world once he can get to England. We commonly have specialists from other countries working at our station, collecting all the information we can give them, and we are very glad to have them. The discovery by scientific workers of newer, easier, and cheaper ways of producing things would simply mean that everybody would adopt them, and we should all be left exactly where we were.

Science thus seemed helpless. But something had to be done. Our agriculture was getting into a terribly serious position, especially in the eastern counties where the conditions are not favourable to grassland and cheap milk production. Farmers were becoming more and more involved in debt; they were reducing staffs, cutting down all expenditure, and their farms were deteriorating. Prices were falling continuously, and our markets were so glutted with imported cheap food that much farm produce became almost unsaleable. Finally the situation became so critical that the Government decided to take the very drastic step of stopping the indiscriminate free importations of food and putting the whole business of food supply on a definitely organised basis.

Of course, it meant giving up Free Trade (or at least free, unrestricted import) and it took our people a long while before they were prepared to give up the old idea of free trade in food, or indeed in anything else. But no alternative could be devised: the opponents could only recommend farmers to go on hoping, a very unsatisfying proposal.

Two methods of control were very seriously considered once it was recognised that the farmer had to be helped. One was the method of putting tariffs on imported foodstuffs. That met with a good deal of favour at first, but the more it was discussed the more serious were found to be its disadvantages. I need not go into the question of exactly what they were: probably the most serious was that the town people did not like it, and in our country, as you know, nine-tenths of the people live in the cities and have to buy their food, and the suggestion of a tax on anything they themselves buy is repulsive. The second method was more popular. It involved the allocation to the home farmers of a certain proportion, called the quota, of the home market, guaranteeing at the same time an agreed price so arranged as to cover a reasonable cost of production and leave a small margin for the farmer. The quota for wheat is 15%; our farmers are told that they can supply 15% of our wheat requirements and that the price given will be forty-five shillings a quarter, i.e. $1.39 per bushel. They can, if they like produce more than that, but they won't get the guaranteed price for anything beyond the 15%; they must dispose of any excess as best they can.

Similarly with other agricultural products; a quota of some kind is arranged and farmers are guaranteed a certain proportion of the home market and a certain price for it. The working out of the scheme is delegated to various non-political and non-government Commissions and Marketing Boards formed of representatives of the producers, the distributors, and the consumers. This method of procedure is making it possible to arrange for contracts between farmers and buyers. Instead of the farmer producing hopefully for a market day where he may receive much or little according to the relative abundance of scarcity of products, he can now work on a contract to supply certain quantities of produce at a certain price; he knows, therefore, what his receipts will be and he can arrange to spend a certain amount on fertilizer, on new implements, better seed, and other equipment. His certainty of some return puts him on the alert for new methods of improving his production.

This system of contracts implies, of course, that the farmer shall maintain a high standard of efficiency and pay his workers a wage corresponding with the price received. You cannot expect any city population to remain content with arrangements that can be represented as keeping up prices of food if there be any suggestion of inefficiency on the part of the farmers; a highly efficient farming community and a satisfactory standard of labour alone can justify the continuance of artificial quotas or the contracts that they imply.

These considerations are making it necessary for our agricultural experts and advisers to consider carefully their duties to the farming community in these new conditions. We have two great functions to perform. First of all we must discover the facts and the underlying principles of crop production and of animal production—finding out how the plant grows, what changes take place when you cultivate the soil, what fertilizers do, how the animal grows and multiplies, how diseases affect the plant and the animal and how they act. This information is required not only for the use of the expert himself, but also for the purpose of building up a sound system of agricultural education; because unless the farming community is adequately educated you cannot expect the town community to support them by agreeing to any

restrictions of food prices. With that call for improved agricultural education has come a fuller recognition of the vital importance of more and more knowledge of the fundamental principles underlying agricultural processes, and this in turn has brought into prominence the necessity for still more fundamental work in biochemistry, soil chemistry, soil physics, and biology; subjects that, not infrequently, have been regarded as purely academic, as luxuries permissible in times of prosperity but legitimate subjects for retrenchment in days of adversity. Yet all experience shows that these so-called academic subjects furnish the material out of which the agricultural expert fashions the soundest advice and the best educational courses for the young farmer. You can not build up a permanent system of agricultural education on simply empirical knowledge; it must be based upon scientifically ascertained facts and principles. Nature is one and indivisible, and although we may find it convenient to distinguish between science and applied science, yet the lines are of our own invention and have no existence in reality.

In England we are not only trying to develop our agricultural education but also to improve the method of presenting it. This, of course, is mainly the business of the educationalist, but the agricultural expert must also know something about it so as to discover how best to shape his material before handing it over to the teacher. Personally I am very interested in this question of rural education, especially in school teaching. When I first turned over to agricultural science from pure chemistry I used to spend one afternoon each week in the village school teaching the children something about the countryside around them. I can no longer do that, but for half an hour every alternate week I broadcast to rural school children during their school hours. Many of our country schools have radio sets, and the British Broadcasting Corporation arranges for talks each afternoon on rural science, travel, geography, history, music—either piano or good gramophone records with explanations by a first class musician. At Rothamsted Dr. Keen and I undertake the rural science course and we justify the giving up of the necessary time (which however is not very much) by the consideration that the rising generation must learn early to appreciate the value of science and accustom themselves to it, just as they early get accustomed to machines and learn to appreciate their value.

And so we go to London every two weeks and spend half an hour talking to the school children in remote country districts, telling them of the inner meaning of many of the things they see happening round about them in the fields and in the school garden: the germination of the seed, the changes brought about by cultivation, the feeding of the plants and animals, giving them in simple language the elementary scientific principles underlying all these things. We hope in the end to build up a new attitude towards science in our countryside, to train up a race of young country people accustomed from the outset to the ideas of science, and who will therefore be able to take the fullest possible advantage of the extension services available to them.

This, of course is in addition to the more usual work of giving farmers' lectures; and I should like to digress for a moment to say how in recent years the interest of farmers in agricultural lectures has increased. When I first went lecturing, twenty-six years ago, I used to have to give the lecture in a room at the hotel on market day after the market was finished. It was

often difficult to get an audience, and sometimes the bar (where of course good liquor was to be had in plenty so long as a man could pay for it) proved a very serious counter-attraction. Often one had to stop after about fifty minutes as the men lost interest, and often too the questions were poor and the discourse worse. But now-a-days when you go lecturing to a farmers' audience you not uncommonly find that the secretary has taken the biggest hall in the town, and that there is a good audience of farmers who have come in by automobile, prepared to stay and listen for as long as you will talk; sometimes the lecture and discussion have to be stopped because the chairman wants to get home. That change has come about because farmers now appreciate much more fully than before the war the part that science plays and must continue to play in agriculture.

All this has quite naturally put upon the agricultural expert the need for further developing agricultural science and for discovering by direct experiment the things that he proposes to tell to farmers, because it is no use talking out of your head to a crowd of farmers; you have to base your talk on actual experiments or good field observation, so that you know the things you say are true because you have seen them for yourself. With the improvement of agricultural science has come a strengthening of the relations between the scientific worker and the farmer, and I am very hopeful that out of the trials and troubles of to-day there will arise new and higher standards in our science and practice. As I see the future our farmers will continue to specialize, yet they will be able to diversify their farming sufficiently well to have two or three strings to their bows instead of only one, so that they may be reasonably sure of a moderate return for their labour.

How do these developments in British agriculture affect Canada? You supply us at the present time with about 50% of the wheat which we import. The 15% which the new quota gives to our farmers is not I think likely to affect you in the slightest degree. First of all, ours is not the same kind of wheat as yours; it is a soft, and not a hard red wheat, and it is not a wheat that our millers like to use to any great extent; 15% is about as far as they are likely to go. A new use has recently developed for English wheat: it is much used for poultry feeding, and it so happens that poultry are markedly increasing in our country so that the amount of wheat they require—which is already considerable—is likely to increase still further; I cannot, therefore, see that our wheat quota is going to injure Canada's exports to us.

You used not to send us 50% of our imports of wheat, indeed it is only quite recently that you have sent so much. Before the war your share was only about 25% but you have increased at the expense of the United States and of Russia. It would of course be interesting to speculate on whether either of these countries is likely to get back sufficient of their old trade to reduce your 50% appreciably. I shall certainly not venture a prophecy, but I cannot see either of them doing that for some long time. Agriculture in the United States seems likely to develop along other lines than the export of wheat. Russia may become a more serious competitor but during the last two years she has sent us but little wheat, and this year practically none. I went through Russia in 1930 to see what I could of the wheat position, and I am expecting to return next Easter, but at present it

hardly appears likely that Russia greatly will injure you as a competitor. I think, therefore, you are reasonably safe in regard to wheat.

With regard to your other products, let us take apples first. We receive from you about one quarter of our total import of apples. But the States send us far more: they supply half our import requirements. It is for you to find out the reasons for this and see if you cannot capture a great deal of the American apple trade. It is not easy because they send us very good stuff which is well known and respected on our markets. We have, of course, a considerable production of apples in England, and this is increasing but there will long be room for you because our consumption is going up. Englishmen especially enjoy three kinds of fruit: apples, bananas and oranges; of these we consume about equal quantities, and very much more than of all other fruits put together. You can, I think, hope for a much bigger trade with England in apples than you have yet developed.

You send us a good deal of cheese, indeed you are second on the list of our suppliers. The first place is held by New Zealand which sends us 2½ times as much as you do—over 1,700 thousand cwt. per annum, against a little over 700 thousand cwt. from Canada. The New Zealand supply has increased while yours of late has not. The New Zealand dairy farmer, however, has many advantages you lack. He can keep his cows out to grass for ten or eleven months of the year and he need give them little but the natural pasture, the beautiful green grass of their dairying valleys. For only a few weeks in the year need the animals be kept indoors and the very competent New Zealand agricultural experts are continually striving to shorten this winter feeding period by improvements in management and fertilizer treatment of the grass. You will therefore always be liable to serious competition from New Zealand, but after all New Zealand is not a very big country, and the dairy regions in New Zealand are not as extensive as yours: they are mainly confined to the plains and valleys. In the hills dairy work is much less promising.

Before the war you used to send us a fair amount of bacon and you still send a little, but only one-eighth of your earlier supply, and only 5 out of every 1000 lbs. that we import. Canadian bacon had indeed disappeared as a distinct article in England. Nearly three-quarters of our imported bacon comes from Denmark, and the Danes have secured this enormous hold on our market because they have taken the trouble to supply precisely the article that our wives want. They have discovered the exact degree of fattiness and of streakiness required in various regions of Great Britain, the proper amount of salt to put in, and the right shade of taste and of quality, with the result that they put bacon on our market which is exactly and precisely what our wives want; and so, naturally, our wives buy it and will continue to buy it, and no system of quotas, preferences, or anything else will prevent them doing it. The English housewife is a very independent-minded person, and you simply cannot make her buy what she doesn't want. She may not always know what she does want, but she knows when she hasn't got it. If you send her the sort of bacon she doesn't want it will remain unsold. You have a lot of hard work before you if you want to oust the Dane from our bacon market.

Looking at all the Canadian agricultural products, I think perhaps your easiest job is to increase the supply of apples. Cheese also you should be able to send over in larger quantity, especially the better qualities. But for all these products there will always be need of a great amount of really hard scientific work if you are going to expand your sales and especially if you want to supply new products and secure a position in markets that you have not yet exploited. One thing you have in your favour, a very strong sentimental preference for anything from Canada. Any article labelled Canadian is sure to attract attention and can be pretty sure of a first sale. But before sending new articles into our markets I strongly recommend you to ascertain by trial that they are what the market wants. If our wives don't like them they will not buy them again, and you will be in danger of losing that enormously valuable asset, their desire to buy things from Canada. Of course all this necessitates a great deal of work at the agricultural experiment stations and colleges to discover what is meant by quality, and how quality is affected by differences in treatment and in environment. This is one of the most difficult of all agricultural investigations, but the successes already attained show that it can be carried out with a considerable measure of success.

However, with all the help of science, and the kindly office of the extension officer and other well-wishers, life can never be made entirely easy for the average farmer. He may be protected by quotas or tariffs and helped by scientific advice as much as you like, but he must always take risks; it is usually a choice of evils, and he has to decide between one or more courses of action neither of which he would choose to take, but he has got to do it. The farmer's life is well illustrated by an incident I once met with in the west of Ireland. There was a great stir because a lady of seventy was going to marry a gentleman of seventy-one. But the matter was explained quite simply by one of her neighbours: "The winter is coming on and the peat has to be got in for fuel and the potatoes have to be lifted and brought in; it was a case of either marrying a husband or buying a donkey." Well, that is very much the farmer's situation. He is called upon to choose between two courses neither of which is exactly what he would like to do. Our job as agricultural experts is to give him more alternatives, to try to make the various possibilities better for him, and the decision between them more easy.

Your farmers, like ours, and you with them just like us, are now passing through times of great stress and great anxiety. But you can find much ground for hope if you look back and think what the farmers of bygone days had to go through when they first came here, and out of the wild forests made the smiling countryside of Eastern Canada thickly set with comfortable farm homes and attractive little towns. Those old French settlers who gave so much to Canada, and the early British settlers who followed them, went through vastly more suffering than anyone now is called upon to face. We do but risk money: they risked their lives. With all our financial anxiety we still possess all that has been handed down to us and all that we have ourselves made: good roads, pleasant homes, towns, healthy surroundings, waters, electricity, and a thousand amenities of which they never dreamed. And it is much the same for the prairie farmers: contrast their lot now with that of the early settlers. Fortunately for us the records of the Red River

settlement were kept, so we know something of their sufferings: how in 1813 a group of Highlanders sent out by Lord Selkirk broke the ground with a hoe, and struggled with English wheats year after year, always failing yet always striving and hoping. The first year the crop was taken by the birds, in later years sometimes by Indians, or more birds, or it failed. Finally after six years all their difficulties seemed overcome: a rich harvest was in sight, when lo! out from the west came a cloud of grasshoppers and devoured everything—wheat, garden produce and every green herb in the colony. The chronicle goes on to say: "This sudden and unexpected disaster was more than they could bear. The unfortunate emigrants, looking up toward heaven, wept." I always think it speaks volumes for their good Scotch upbringing that they did no more than that.

However great your troubles now appear, you in Canada can look back with pride on the spirit of endurance that enabled those earlier settlers to win through all their trials and troubles—which after all were far greater than those of our day. It is your duty and your privilege to rekindle that wonderful spirit of endurance; to keep alive the flame of undying hope and imperishable faith in the future of your country; to foster

> " . . . . . th' unconquerable will,
> And courage never to submit or yield."

If you persevere through these dark days you will win through, just as they did. Stand firm, then, so that, in the years to come, men may look back upon these days as times when Canada was learning new lessons, and fortified by new experiences passed through the dark portals of today to a brighter hope and promise for tomorrow.

SOME ASPECTS OF THE OVERSEAS MARKETS FOR CANADIAN HONEY[1]

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A study of the geography of world production and consumption of honey for recent years shows that the surplus-producing countries have been largely those of the western hemisphere—North, Central and South America and the West Indies—together with New Zealand, Australia and Russia. The importing countries of major significance have been but two in number—Germany and the United Kingdom. Although during the post-war period Netherlands, Denmark, France, and Italy have been regular or intermittent importers of honey, they have not occupied a position comparable in importance to that of Germany or the British Isles. This paper will be restricted to a consideration of the market situation and outlook in the two first-mentioned importing countries.

The German Market Situation

Germany, considered over a period of years, has held virtually undisputed sway as the heaviest importer of honey for domestic consumption. Gaining steadily after the period of inflation and currency stabilization which ended in 1924, Germany's honey imports reached a total in excess of 21,000,000 pounds for the year 1929. This is to be compared with 11,000,000 pounds for the United Kingdom also at a post-war peak in that year.

As might be expected, German honey imports have shown a heavy decline for 1930 and 1931, standing in the latter year at slightly less than half of the 1929 total. Economic depression and disorder combined with a heavy tariff increase at the beginning of 1930 may be considered as the chief contributing causes. This point will be touched upon later.

German honey imports, over the period noted, have been furnished chiefly by the United States, (mainly California), Cuba, Chile, Guatemala, Haiti, Dominican Republic, Russia, and Mexico. Imports of Canadian honey have been negligible, rarely exceeding 2% of the total and comprising less than 1% for the year 1931.

From the standpoint of the German consumer, honey can perhaps best be described as a "conventional luxury". While much more widely used than in England or possibly than on this continent, there is a strong tendency toward curtailment in times of economic stress. Substitution by artificial honey is also a possibility. An evenly granulated, full flavored honey of medium light (light or light amber) colour meets with the most widespread consumer preference. There is no reason to believe that inability to meet these requirements has had any effect in keeping Canadian honey from this market.

The Outlook in the German Market

Any future change in the status of Canadian honey on the German market must necessarily be in the way of improvement since honey from the

[1] The data and analysis upon which this paper is based were assembled and undertaken as part of an industry analysis of California bee culture. Voorhies, Edwin C., F. E. Todd, and J. K. Galbraith. Economic Aspects of the Bee Industry. California Agr. Exp. Sta. Bul. (in press). Also Honey Marketing in California by the same authors. California Agr. Exp. Sta. Bul. 554: 1-31. July, 1933.

[2] Giannini Foundation of Agricultural Economics.

Dominion has never been sold there in significant quantities. It would be fatal however, to look in too sanguine a fashion upon development under such conditions. From the short-time point of view it is to be noticed that German imports are in a state of severe decline—a decline which is a joint function of two particularly cancerous factors—tariff[3] and depression. It is of further significance that the decline in imports fell heavily on honey from the United States, which had previously supplied from one-quarter to one-third of the total. This honey, like that from Canada, is of desirable quality and is merchandised in a reasonably acceptable manner. Production and export of this quality has become geared to a considerably higher price than is required to bring Cuban, Haitian, or Chilean honey on the market. Canadian honey of the lighter grades, at the same price as Cuban honey, would unquestionably outsell it. At the same time the Cuban producer can probably continue to put his crudely produced, barrelled product on the German market at prices lower than those which will entice the Canadian producer. Under present conditions in Germany the consumer, whatever his taste, must buy the cheapest product obtainable. In terms of a familiar economic dogma, the West Indies produce low-quality honey at comparative advantage, while the Canadian or United States beekeeper produces a higher quality product also at comparative advantage. With current demand shifting to the former in the German market, the short-time outlook does not appear hopeful.

TABLE 1.—IMPORT VALUE (PER POUND) OF HONEY FROM BRITISH WEST INDIES, NEW ZEALAND, CANADA AND CHILE AT UNITED KINGDOM PORTS, 1925-1931. (EXPRESSED IN PER CENT OF VALUE OF UNITED STATES HONEY)*

Country	1925	1926	1927	1928	1929	1930	1931
United States	100	100	100	100	100	100	100
British West Indies	83	85	90	84	95	82	75
New Zealand	105	102	118	141	151	149	126
Canada	133	121	113	124	112	134	103
Chile	87	68	71	65	70	74	50

* The average yearly import value of honey (per pound) coming into United Kingdom ports from the more important sources of supply is shown. In each year the average per-pound value of honey from the United States is represented as equalling one hundred and hence the per-pound value of honey from other countries becomes a per cent of the average value of United States honey for that year. (Computed from Trade of the United Kingdom, annual issues.)

Taking a longer-time viewpoint, and assuming the eventual recovery of economic order, there is little doubt that Germany will again increase purchases of honey. Assuming the equally unpredictable amelioration of tariffs, this increase would unquestionably be accentuated. In the light of past developments it seems logical to assume that demand for better-quality honey will accompany this change. Given an aggressive and well organized merchandising policy there is every reason to believe that Canadian honey will participate in this market with an equal or even differential advantage as compared with the product from other countries. The nature of German-consumer preference may further open a market for certain stronger flavored or slightly darker honeys than find favour in the home or British market.

[3] The German tariff on honey, expressed at par of exchange, was increased from approximately 4½ to 7 cents a pound at the beginning of 1930 and from the latter figure to approximately 10.8 cents a pound in 1933.

The British Market

The United Kingdom ranks second to Germany as a world honey market[4] but from the standpoint of Canadian producers is easily the most important of the two. Honey imports by the United Kingdom have ranged between seven and ten million pounds in recent years and have not shown the drastic decline which has characterized German imports during the depression period.

Until 1928 the United Kingdom drew its honey supply from three main sources—United States, British West Indies, and New Zealand. Canada, Cuba, Chile and other countries contributed somewhat smaller amounts. Within the last three years, however, Canadian honey has made striking progress on this market taking second place among the various competing countries in 1931.

An important sequel to this development is to be gleaned from an examination of the relative per-pound valuation of honey imported by the United Kingdom from different sources. Taking the import valuation of United States honey on a per-pound basis as equalling a hundred for each of the years from 1925 to 1931, New Zealand and Canadian honeys commanded a substantial premium ranging in the case of the latter from 3 to 34% (Table 1). Honey from the British West Indies, chiefly Jamaica, has never been very satisfactorily standardized and prepared for export. The price at which it comes on the British market is apparently in keeping therewith.

Turning to the extent and nature of consumer demand in the United Kingdom it is worthy of note that per-capita comsumption of honey is by no means as high as in Germany. Particularly is this so in what we may be pleased to call "ordinary times". Honey in England occupies a position in the diet not dissimilar to that on this continent and is best described as an occasional breakfast sweet and spread. A Ministry of Agriculture and Fisheries Bulletin summarizes consumer preference as follows: "Light-coloured extracted honey sells more readily than dark-coloured although in the north of England dark honey sells more readily than in the south . . . . in general clear and set honeys are in about equal demand. A set honey of about the consistency of cream is generally preferred to solid, coarsely set honey."[5] It will be observed that there is nothing in the above statement which is otherwise than favourable to well merchandised Canadian honey, particularly the clover honeys.

The Outlook on the British Market

The initial consideration of the outlook for Canadian honey on the British market reveals a decidedly different picture to that for Germany. Here the product is found to be well established and relatively well known. Tariff troubles do not appear imminent although the fact that two of the three leading competitors are also British countries does not indicate any substantial differential advantage in this regard. Unstable currencies react against honey exports as against other export trade but this situation can scarcely be conceded to be permanent. The United Kingdom, while using a smaller volume of honey than Germany, pays a higher price per pound and

[4] Imports of the United Kingdom in 1931 were slightly in excess of those of Germany. Reference here is to the years 1925 to 1931 inclusive.

[5] Ministry of Agriculture and Fisheries, Report on the Marketing of Honey and Beeswax in England and Wales, p. 18-19. 1931.

requires a higher quality. That Canadian honey is meeting consumer requirements is being demonstrated.

At first glance there can be little doubt that the British market presents a not unfavourable picture to the Canadian producer. On the other hand the vitally important fact remains that the purchasing power of the British consumer will continue to determine in large measure the volume of honey that can be moved on this market at any given price, or the price at which any given volume can be moved. The outlook for honey in the United Kingdom, as for other products, remains not exclusively but in large part a function of the prosperity of the country. Likewise it depends on the closely related factor of ability to make purchases abroad as determined by the willingness of other countries to make reciprocal purchases from the United Kingdom. The exploitation of a market cannot be long sustained as a one-sided process.

Finally it should be noted that Canada has in New Zealand a quality-producing and aggressively-merchandising competitor. Poor crop conditions have kept New Zealand out of the British market to some extent in 1930 and 1931, perhaps furnishing thereby a propitious opportunity for Canada. The condition will presumably not continue and should there be any curtailment in progressive sales policy on the part of Canadian producers, the result might be unpleasant to predict. There is also Jamaica, with perhaps unequalled honey resources, making strong efforts to overcome a long-standing and not entirely unjustifiable discrimination against her product on the British market.

Summary

1. The surplus honey producing areas of the world are in North, South and Central America, the West Indies, New Zealand and Russia. Germany and the United Kingdom are the great importing countries.

2. The German market, to which Canada supplies but negligible quantities, draws primarily from United States, Cuba, Chile, Guatemala, Haiti, St. Domingo and other countries. Tariffs and depression have greatly reduced imports since 1930.

3. The British market, for which United States, British West Indies, Canada and New Zealand are the main sources of supply, has been better maintained during the depression period. Canada has increased her relative place and Canadian honey prices are relatively above those of other countries except New Zealand.

4. The outlook for Canadian honey in the German market is not favourable from the short-time standpoint. From a longer-time point of view prospects are somewhat brighter. In the British market Canada at present occupies a relatively favourable position. Maintenance of this position will require a continuance of progressive sales policy.

BIBLIOGRAPHY

The data, upon which the foregoing paper is based, have been drawn from primary and secondary sources far too numerous for individual mention (see footnote 1, page 1). Statistical material was derived from:

1. Statistisches Reichsamt. Der auswartige Handel. Monthly and annual issues.
2. Trade of the United Kingdom. Monthly and annual issues.
3. United States Department of Commerce, Bureau of Foreign and Domestic Commerce: Foreign Commerce and Navigation of the United States. Monthly and annual issues.
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ABSTRACT
STUDIES ON BACILLUS CALMETTE-GUERIN (B.C.G.) AND VACCINATION AGAINST TUBERCULOSIS

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[Abstract prepared from Canadian Journal of Research *9:* 128-136, 1933][2]

This paper summarizes the results of a long investigation made by the Dominion Department of Agriculture at the Animal Diseases Research Institute, Hull, P.Q., into the question of vaccination of cattle against tuberculosis. The studies and trials have extended over a period of eight years. The observations and conclusions are clearly presented and make a valuable contribution to this much discussed and controversial subject of B.C.G. vaccination.

The first part of the report deals with the study of resistance to tuberculosis of cattle vaccinated with B.C.G. and, for comparison, of unvaccinated cattle. These cattle were exposed for various periods of time to natural sources of tuberculous infection. The conditions to which the animals were subject from the time of birth for the whole duration of the resistance and immunity trials are clearly set down. Exposure to infection was by natural means, through the ingestion of raw milk, followed by cohabitation with tuberculous cattle in stables and in pastures. The hazards of exposure were equalized as far as practicable by alternating the locations of individuals and groups of animals in stables and in pastures, and with the object of maintaining environmental and feeding conditions and sources of infection comparable to those prevailing in a herd of tuberculous cattle on a farm. The total number of cattle is 107, of which 72 have completed their trial. These, consisting of 44 vaccinated cattle and 28 unvaccinated controls, died or were killed. Their ages range from 2 months to 4½ years and in each case a thorough necropsy under laboratory conditions, microscopical examinations and animal test inoculations were carried out. Regardless of age or the duration of the trial, it was found that the percentage of cattle free from tuberculosis was approximately the same for the vaccinated as for the unvaccinated, namely 20.5% and 21.4%, respectively.

The cattle are divided into five age groups, between one year and under and up to four and a half years, and figures for each group are given in tabulated form. Some difference in favour of the vaccinated cattle up to 18 months of age is indicated, but in all cattle over 2 years of age, both in vaccinated and unvaccinated, tuberculosis was present to a greater or lesser degree. Although there is but little difference in the incidence of tuberculosis in the vaccinated and unvaccinated groups, there is some evidence of a greater degree of resistance in cattle up to 2½ years of age, and as judged by the kind and extent of tuberculous lesions revealed at autopsy. Extensive tuberculous involvement was found in 26% of the vaccinated and 53% of the unvaccinated groups under 2½ years of age, but in trial durations of 2½ to 4½ years the percentage of cattle with slight, moderate and extensive tuber-

[1] Chief Pathologist.
[2] Acknowledgement is made to Dr. Watson for his courtesy in preparing this enlarged abstract of his paper for readers of *Scientific Agriculture*.—Editor.

culosis, 25%, 25% and 50% respectively, is the same for the vaccinated and unvaccinated groups, and no greater resistance was shown by the former than by the latter. Such increased resistance as may follow B.C.G. vaccination of new born calves declined and soon disappeared under exposure to infection and with the approach of early maturity, and was apparently lost in young cows under the strain of gestation and lactation. Approximately 80% of the cattle developed tuberculosis to a variable extent, but at a slower rate of development and progress in the early life of the vaccinated animals, thus indicating some increased resistance which possibly would be more pronounced if vaccination could be applied under conditions where the exposure to infection is slight and resistance is not broken down by the heavy strain to which breeding cattle, and especially dairy cattle of high production, are subjected.

TABLE 1.—VACCINATED AND UNVACCINATED CATTLE FREE FROM TUBERCULOSIS

Age groups	Number of cattle			Free from tuberculosis, %	
	B.C.G.	Controls	Total	B.C.G.	Controls
Up to 1 year	5	4	9	100	75
1 to 1½ years	8	3	11	25	0
1½ to 2 years	14	9	23	14	33
2 to 2½ years	9	4	13	0	0
2½ to 4½ years	8	8	16	0	0
All cattle	44	28	72	20	21
(*Cumulative*)					
Up to 1 year	5	4	9	100	75
Up to 1½ years	13	7	20	54	43
Up to 2 years	27	16	43	33	37
Up to 2½ years	36	20	56	25	30
Up to 4½ years	44	28	72	20	21

TABLE 2.—VACCINATED AND UNVACCINATED CATTLE WITH TUBERCULOUS INVOLVEMENT

Age group	Number of cattle		With tuberculosis, %			
			Slight	Moderate	Extensive	Total
Up to 1½ years	B.C.G.	13	38	8	0	46
	Controls	7	28	28	0	56
1½ to 2½ years	B.C.G.	23	30	35	26	91
	Controls	13	8	15	53	76
2½ to 4½ years	B.C.G.	8	25	25	50	100
	Controls	8	25	25	50	100
All cattle up to 4½ years	Totals:—					
	B.C.G.	44	32	25	22	79
	Controls	28	18	21	39	78

The second part of the report covers a long period of laboratory propagation and study of the Calmette-Guérin tubercle bacillus. It is recalled that this bacillus, B.C.G., originated from a highly virulent bovine strain and that, according to Calmette and Guérin, during 13 years of cultivation

on a special bile-potato media its virulence was slowly attenuated, first for one species of susceptible animal and then for another until, in 1921, after 230 serial passages, it was said to have completely lost all power to produce tuberculosis. B.C.G. vaccination consists of the injection into the animal or human body of these living, attenuated tubercle bacilli, and the possible danger that might arise from this procedure has long been a very contentious question and the subject of many investigations in different countries, with not a little conflict in the reported results.

Three B.C.G. cultures were received direct from the Pasteur laboratories in France, one in the year 1924, the second in 1925, and the third in 1927, each of which was propagated for succeeding generations up to the year 1932, and tested at repeated intervals for virulence and pathogenicity. In all, tests of 145 subcultures, representing descendants to the 121st generation, were made on over 500 guinea pigs. In approximately 56% of the test animals there was no evidence of tuberculosis. Slight, or localized, or apparently healed lesions were found in 40% of the guinea pigs, but typical tuberculosis, reinoculable from animal to animal, in series, or by reisolation of the culture and subsequent inoculation, developed in 4% of the test animals. Actually, only 6 of the 145 cultures tested proved to be virulent for guinea pigs, and these were able to cause progressive tuberculosis, reinoculable from animal to animal. It is interesting and significant to note that these 6 virulent cultures were obtained at different periods and from different generations or descendants between the years 1924-1928 inclusive, the first strain furnishing 3 virulent descendants, the second, 2 virulent descendants, and the third 1 virulent descendant. During four years of subsequent cultivation none of the cultures tested proved to be virulent for guinea pigs. Each strain was found to possess an unfixed potential virulence, manifested but rarely and only in the 1924-1928 descendants. Continuing under serial cultivation and periodic return to the special bile-potato media which served for the attenuation of the original cultures, virulence has apparently disappeared and none of the later descendants tested, since 1929, have caused a progressive reinoculable tuberculosis in laboratory animals. These results offer a confirmation of the reported experiments and evidence by a number of investigators in different countries in disproof of the claim that B.C.G. was completely and absolutely devoid of virulence and that its properties were hereditarily fixed, especially in connection with the cultures distributed in the years 1924-1927.

The conclusion reads as follows:

"At this present time we can make the statement on positive proof evidence that the parent strains of B.C.G., as they came to us, and their early descendants possessed an unfixed potential virulence capable of exaltation on the one hand and of further and complete reduction on the other, each of which has been accomplished; and, on negative evidence, that the latter descendants of the same strains (1929-1932), by continuous reproduction and periodic return to bile media in accordance with Calmette's recommended procedure, have become incapable of causing progressive, reinoculable tuberculosis in laboratory test animals."

A STUDY OF THE RELATION OF ENVIRONMENT TO THE DEVELOPMENT OF THE UREDINIAL AND TELIAL STAGES OF THE PHYSIOLOGIC FORMS OF *PUCCINIA GRAMINIS AVENAE* ERIKSS. AND HENN[1]

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Introduction

The classification of the physiologic forms in *Puccinia graminis avenae* Erikss. and Henn., as in most cereal rusts, has been based upon the assumption that the types of infection produced by the various forms on differential hosts in the seedling stage were not significantly different under various environmental conditions. The validity of this assumption has been questioned in recent years. Wide fluctuations have been observed to occur in the types of infection produced on certain differential hosts apparently due to a change in the environment. The present study was undertaken to determine the relation of certain environmental factors, particularly temperature, to the development of the physiologic forms of *P. graminis avenae.*

The relation of the environment to two stages of development of the physiologic forms of this rust was determined. First, a study was made of the types of infection produced by the uredinial stage on certain varieties and strains of *Avena* spp. used as differential hosts; and, second, of the formation of the telia by the different physiologic forms.

The greater part of the study was concerned with the relation of one environmental factor. temperature, to the development of the physiologic forms, although the effects of ultra-violet radiation and atmospheric humidity upon them also received attention.

This investigation was commenced in 1929 at the Dominion Rust Research Laboratory, Winnipeg, Manitoba, and a preliminary report (*15*) was published in 1930. Since that time the work has been continued and extended, part being done in the Dominion Rust Research Laboratory and part in the Department of Plant Pathology, University of Wisconsin, Madison, Wisconsin.

Physiologic Specialization in *Puccinia graminis avenae*

Review of literature on physiologic specialization in *Puccinia graminis avenae*

The composite nature of *Puccinia graminis* Pers. was demonstrated by Eriksson (*5*) in 1894. At this time the stem rust of *Avena* spp. was recognized as a distinct biologic race of *Puccinia graminis* and was termed *Puccinia graminis* f. *avenae.* Although further specialization was shown to occur in *Puccinia graminis tritici* by Stakman and Piemeisel (*42*) in 1917, it was not demonstrated in *P. graminis avenae* until 1923, when Stakman, Levine and

[1] Submitted to the Faculty of the Graduate School of the University of Wisconsin in partial fulfilment of the requirements for the degree of Doctor of Philosophy.
[2] Plant Pathologist.

Bailey (*45*) reported the occurrence of at least four, and possibly five biologic forms in this rust.

In 1925, Bailey (*1*) gave the results of a more intensive study of the problem and showed that, of the five physiologic forms isolated, forms 1, 2 and 5 occurred in the United States and Canada. Forms 3 and 4, more virulent than the others, were not isolated from any collections of oat stem rust made in America. Form 3 was shown to occur in South Africa and Sweden, while form 4 was isolated only from a collection of oat stem rust obtained in Sweden. A further study by Bailey (*2*) of collections of *P. graminis avenae* made in Canada in 1924 showed that forms 1, 2 and 5 were present again, but that forms 3 and 4 were apparently absent.

Gordon and Bailey (*14*) in 1928, demonstrated the existence of six physiologic forms of *P. graminis avenae* in Canada. These forms were isolated from approximately 600 collections made in Canada during the three-year period 1925-1927. In addition to forms 1, 2 and 5 already known to occur there, forms 3, 4 and 6 were isolated for the first time. Form 6 is the most virulent physiologic form of oat stem rust yet isolated, as more than 300 varieties and strains of *Avena* spp. are susceptible to it. Although forms 1, 2 and 5 were the most prevalent, a few isolations were made of forms 3, 4 and 6.

Waterhouse (*54*), in 1929, reported five physiologic forms of *P. graminis avenae* as occurring in Australasia. Forms 1 and 2 were found by him to be the most prevalent and widespread during the period 1925-1929. Forms 6 and 7 were isolated only during the years 1928 and 1929. Form 3 was first isolated in 1929. Forms 1 and 7 were also isolated by him from cultures derived from a barberry which had been artificially inoculated with teliospore material collected in Ireland. The cultures of these two physiologic forms differed in colour from the Australian forms of oat stem rust. While the cultures of Australian forms, according to Ridgway's Colour Standards, were classified as "morocco red", these were "xanthine orange".

In 1930, Levine, Stakman and Stanton (*27*) reported the occurrence of forms 1, 2 and 5 in the United States during the five-year period 1923-1927. Form 2 was the most prevalent physiologic form there during this period. Form 1 was isolated commonly, but form 5 was found to be present only in 1927. Although they were unable to isolate and identify the specific forms, evidence was obtained which showed that physiologic forms of *P. graminis avenae* more virulent than forms 1, 2 and 5 probably were present during 1923 and 1924.

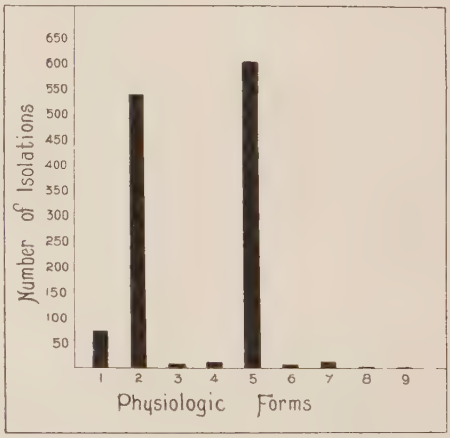
The results of an investigation of the physiologic specialization of *P. graminis avenae* in Sweden were reported by Tedin (*51*) in 1930. From a study of the types of infection produced on the differential hosts by a number of collections of oat stem rust, it is apparent that five physiologic forms are present there. These are forms 3, 4, 6, 7 and 8—all more virulent physiologic forms than those prevalent in the United States and Canada.

PHYSIOLOGIC FORMS OF *Puccinia graminis avenae* PRESENT IN CANADA DURING THE PERIOD 1925-1930

An extensive study of the physiologic specialization in *P. graminis avenae* in Canada was carried on at the Dominion Rust Research Laboratory,

Text Figure 1. The geographic distribution of the oat stem rust collections cultured during the period 1925-1930.

Text Figure 2. The total number of collections of oat stem rust cultured from each province during the period 1925-1930.



Text Figure 3. A comparison of the total number of isolations of the nine physiologic forms of *P. graminis avenae* made in Canada during the period 1925-1930.

Winnipeg, Manitoba, during the six-year period 1925-1930. Collections of oat stem rust were obtained each year from the different provinces and were cultured in the greenhouses. The geographic distribution of these collections is shown in Text Figure 1. The total number of collections of oat stem rust cultured from each province during the period mentioned is shown by means of a graph in Text Figure 2. The relative prevalence of the rust geographically and the facilities afforded for obtaining the collections governed the number cultured each year from the different provinces. From a total number of 1070 collections cultured, 904, or approximately 85%, were obtained in the Western Provinces, as is shown in Table 1. The majority of the collections cultured were secured from the provinces of Manitoba and Saskatchewan.

TABLE 1.—DATA CONCERNING THE TOTAL NUMBER OF COLLECTIONS CULTURED FROM EACH PROVINCE DURING THE PERIOD 1925-1930.

Provinces	Total number of collections cultured	Percentage of total number
Western Provinces		
British Columbia	4	.4
Alberta	62	5.8
Saskatchewan	334	31.2
Manitoba	504	47.1
Eastern Provinces		
Ontario	59	5.5
Quebec	36	3.4
New Brunswick	23	2.2
Nova Scotia	39	3.7
Prince Edward Island	9	.8
Total number	1070	
Western Provinces	904	84.5
Eastern Provinces	166	15.5

During the period 1925-1930, nine physiologic forms of *P. graminis avenae* were isolated from the collections of oat stem rust made in Canada. The identification of these physiologic forms was not carried out under controlled environmental conditions. The mean types of infection produced by the nine physiologic forms on the differential hosts are shown in Table 2, and are illustrated by photographs in Plates I - III.

The frequency of occurrence of the different physiologic forms varied greatly, as determined by the number of isolations which were made of each form. Forms 1, 2 and 5 were most prevalent each year, as well as during the whole six-year period 1925-1930. During this period, 1257 isolations were made. Of this number 1213 isolations, or 96.5% consisted of forms 1, 2 and 5. The extreme frequency of isolation, particularly of forms 2 and 5, as compared with that of the other physiologic forms, is shown graphically in Text Figure 3. Forms 3, 4, 6, 7, 8 and 9 were isolated but rarely, a result indicating a limited occurrence of these particular physiologic forms of *P. graminis avenae* in Canada. These physiologic forms are more virulent than the commonly occurring forms 1, 2 and 5. In Table 3 is shown the total

number of isolations of each physiologic form as well as the total number of isolations of physiologic forms, made from collections obtained from the different provinces during the period 1925 - 1930.

TABLE 2.—THE MEAN TYPES OF INFECTION PRODUCED BY THE NINE PHYSIOLOGIC FORMS ON THE DIFFERENTIAL HOSTS.

Physiologic forms	Control host	Differential hosts		
	Victory	White Russian	Richland, Heigira Strain Monarch Strain	Joanette Strain Strain 703
1	4	3–c	2	1
2	4	3–c	2	4
3	4	4	2	1
4	4	4	4	1
5	4	3–c	2	X
6	4	4	4	4
7	4	4	2	4
8	4	3–c	4	4
9	4	3–c	3–c	4

TABLE 3.—DATA CONCERNING THE NUMBER OF ISOLATIONS OF PHYSIOLOGIC FORMS MADE DURING THE PERIOD 1925-1930.

Provinces	Physiologic forms									Total isolations by provinces
	1	2	3	4	5	6	7	8	9	
British Columbia	–	4	–	–	2	–	–	–	–	6
Alberta	4	30	–	–	41	–	–	–	–	75
Saskatchewan	18	161	2	4	204	1	–	–	–	390
Manitoba	40	267	5	5	259	6	6	1	–	589
Ontario	2	36	1	2	26	–	6	–	–	73
Quebec	5	18	–	–	19	–	1	–	–	43
New Brunswick	1	9	–	–	19	–	–	–	–	29
Nova Scotia	4	11	–	–	24	–	1	1	1	42
Prince Edward Island	1	1	–	1	7	–	–	–	–	10
Total isolations by forms	75	537	8	12	601	7	14	2	1	1,257

Physiologic specialization of *P. graminis avenae* in Canada does not appear to be extensive, if one is permitted to judge from the limited number of physiologic forms isolated during the period 1925-1930. From the standpoint of the production of a desirable stem rust resistant variety of oats, it does not seem at present to be a serious factor. Sufficient resistance to forms 1, 2 and 5, the most prevalent physiologic forms, is available in the differential hosts, Richland, Heigira Strain and Monarch Strain (Table 2). These hosts are also quite resistant to forms 3 and 7, as well as being moderately resistant to form 9. Such forms as 4, 6 and 8, which are capable of infecting heavily these hosts, have occurred but rarely during the period 1925-1930. However, it is possible that these forms may become more common in the future. It is of interest to note that only forms 3, 4, 6, 7 and 8 were isolated by Tedin (*51*) from collections of oat stem rust made in Sweden, all of which are more virulent than those forms commonly occurring in Canada.

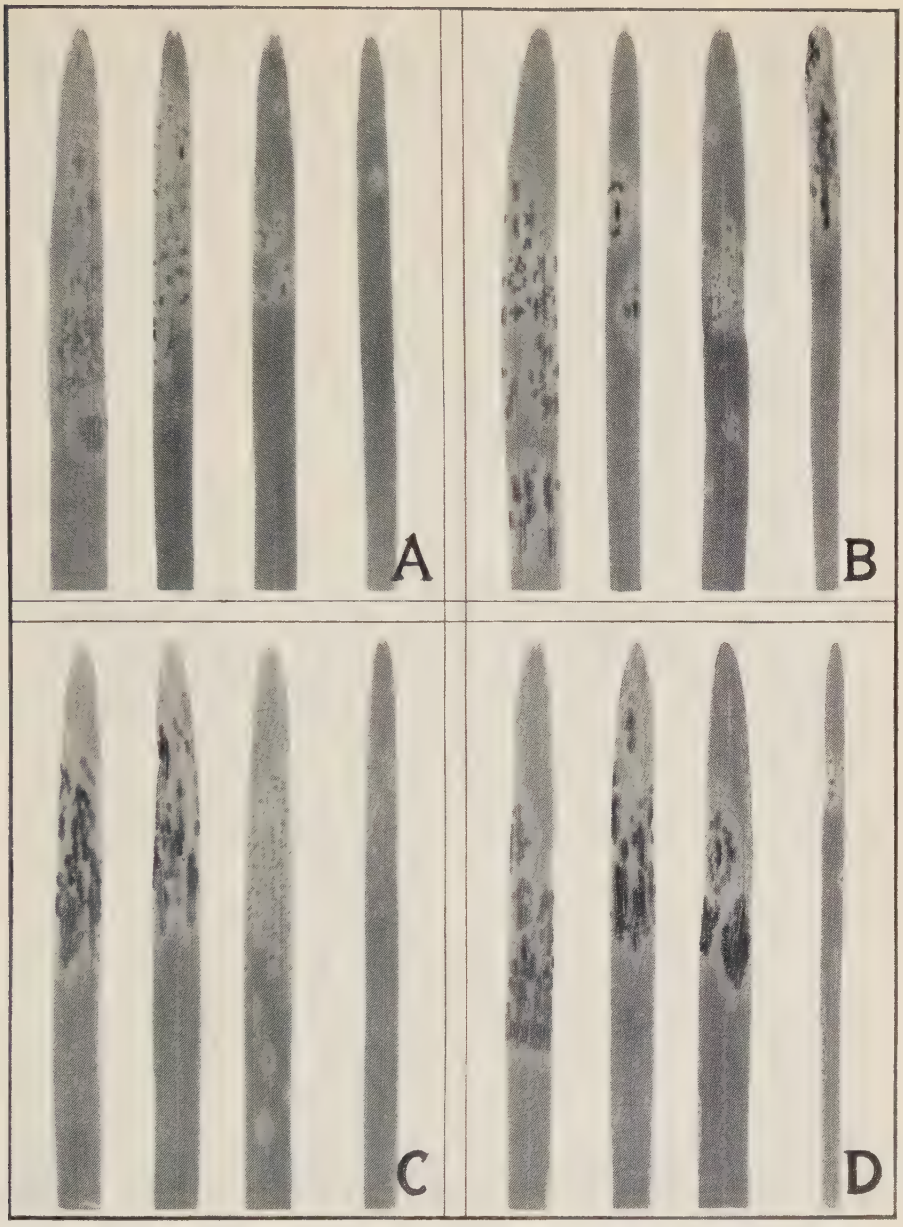


PLATE I.

Figure A. The types of uredinial infection produced by *P. graminis avenae*, form 1, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure B. The types of uredinial infection produced by *P. graminis avenae*, form 2, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure C. The types of uredinial infection produced by *P. graminis avenae*, form 3, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure D. The types of uredinial infection produced by *P. graminis avenae*, form 4, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

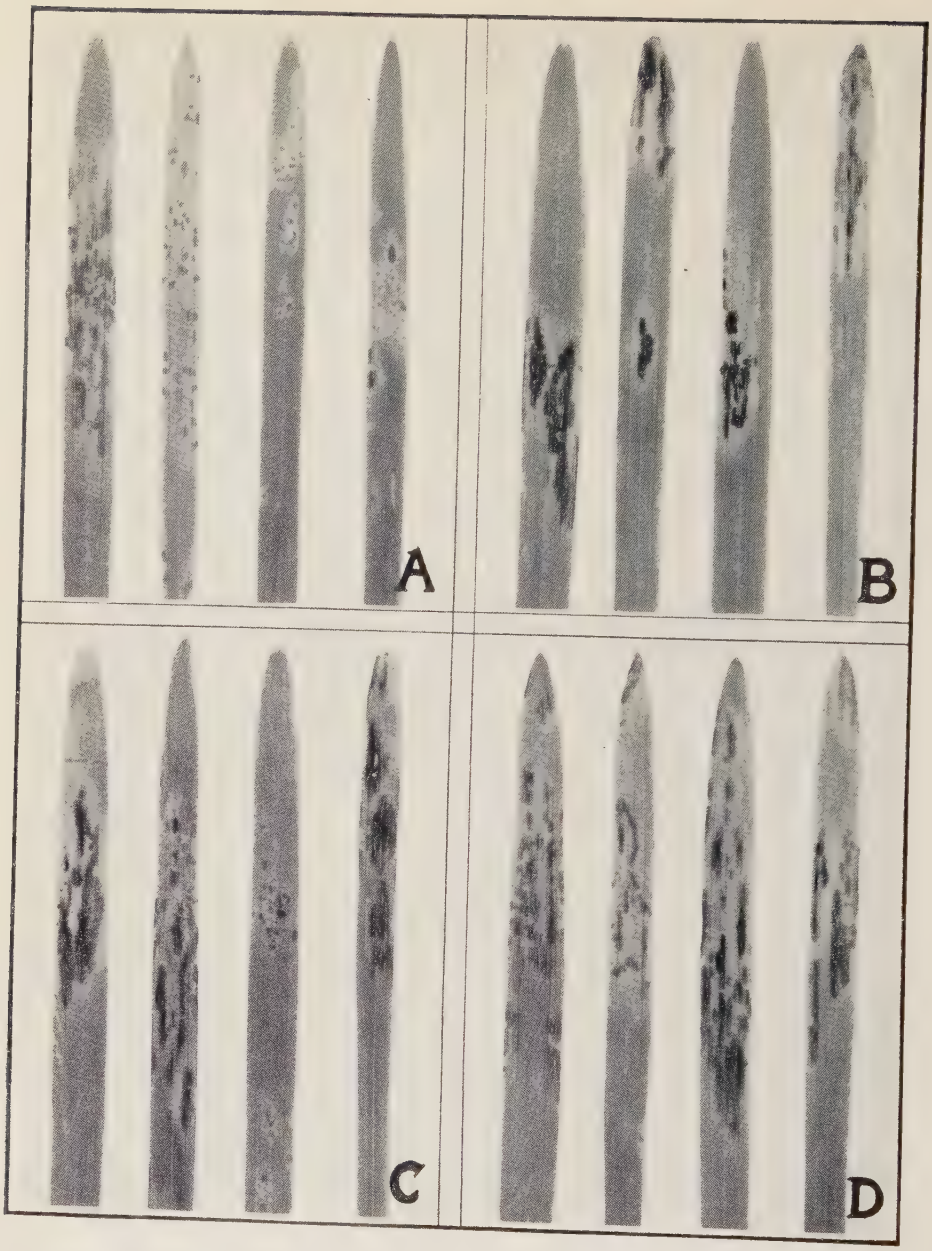


PLATE II.

Figure A. The types of uredinial infection produced by *P. graminis avenae*, form 5, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure B. The types of uredinial infection produced by *P. graminis avenae*, form 6, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure C. The types of uredinial infection produced by *P. graminis avenae*, form 7, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure D. The types of uredinial infection produced by *P. graminis avenae*, form 8, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

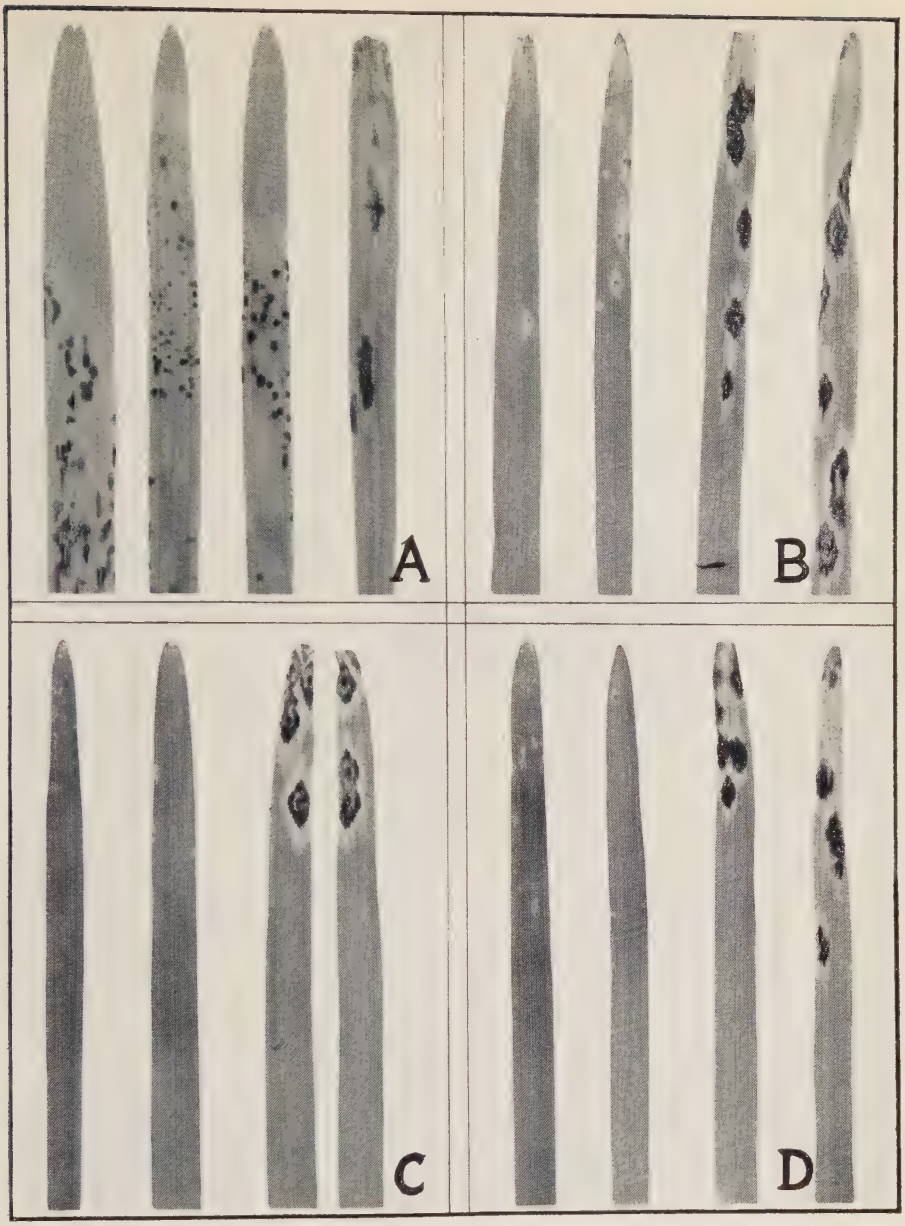


PLATE III.

Figure A. The types of uredinial infection produced by *P. graminis avenae*, form 9, on four hosts in the seedling stage. Left to right: One leaf of Victory, White Russian, Richland and Joanette Strain.

Figure B. The types of uredinial infection produced by *P. graminis avenae*. form 1, on Joanette Strain in the seedling stage when kept at four temperatures. Left to right: One leaf of Joanette Strain kept at temperatures of 12°, 16°, 24° and 28°C.

Figure C. The types of uredinial infection produced by *P. graminis avenae*, form 3, on Joanette Strain in the seedling stage when kept at four temperatures. Left to right: One leaf of Joanette Strain kept at temperatures of 12°, 16°, 24° and 28°C.

Figure D The types of uredinial infection produced by *P. graminis avenae*, form 4, on Joanette Strain in the seedling stage when kept at four temperatures. Left to right: One leaf of Joanette Strain kept at temperatures of 12°, 16°, 24° and 28°C.

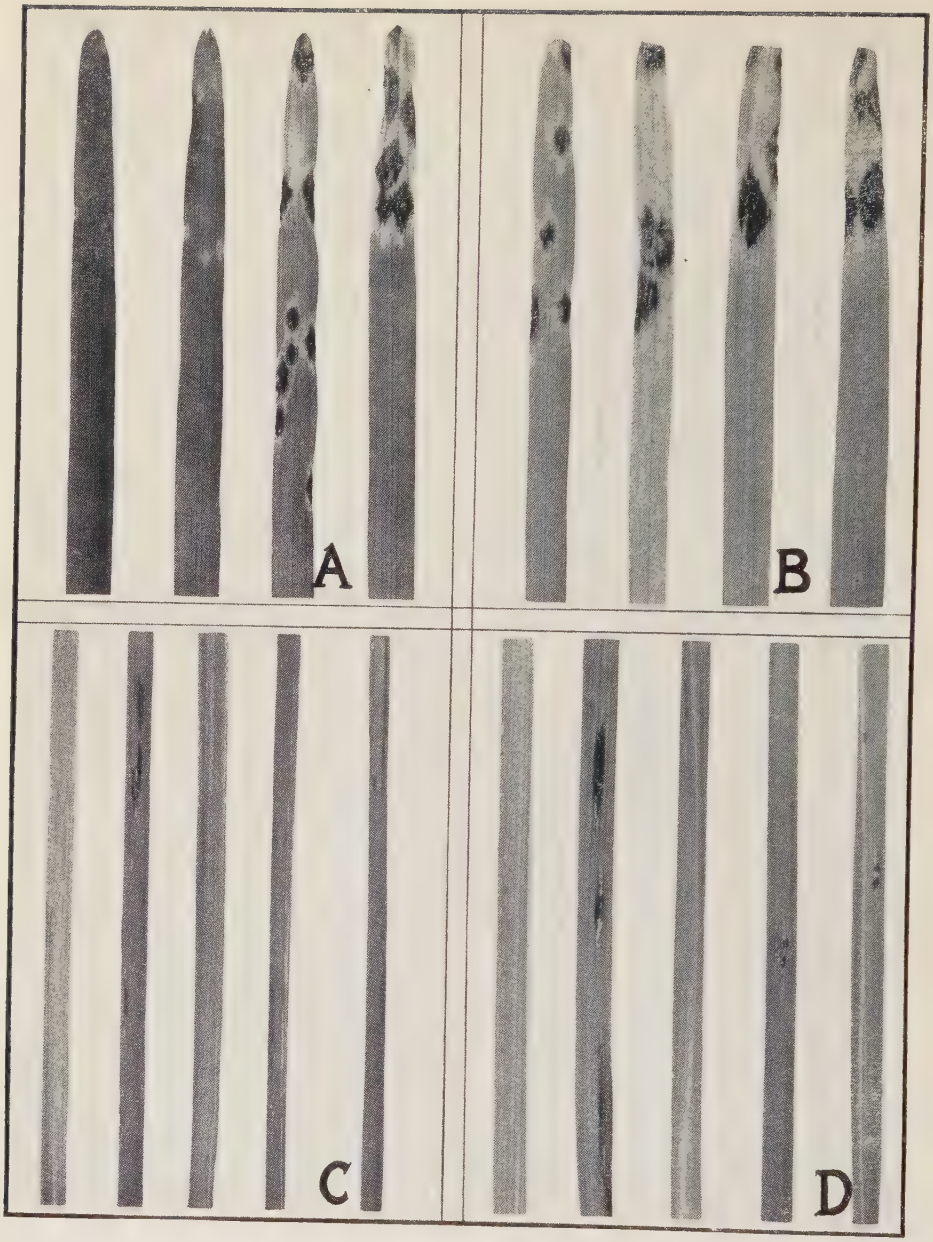


PLATE IV.

Figure A. The types of uredinial infection produced by *P. graminis avenae*, form 5, on Joanette Strain in the seedling stage when kept at four temperatures. Left to right: One leaf of Joanette Strain kept at temperatures of 12°, 16°, 24° and 28°C.

Figure B. The types of uredinial infection produced by *P. graminis avenae*, form 2, on Joanette Strain in the seedling stage when kept at four temperatures. Left to right: One leaf of Joanette Strain kept at temperatures of 12°, 16°, 24° and 28°C.

Figure C. The types of uredinial infection produced by *P. graminis avenae*, forms 1, 2, 3, 4 and 5, on Joanette Strain in the mature stage when kept at a temperature of 12°C. Left to right: One stem of Joanette Strain infected by forms 1, 2, 3, 4 and 5, respectively.

Figure D. The types of uredinial infection produced by *P. graminis avenae*, forms 1, 2, 3, 4 and 5, on Joanette Strain in the mature stage when kept at a temperature of 16°C. Left to right: One stem of Joanette Strain infected by forms 1, 2, 3, 4 and 5, respectively.

PLATE V.

Figure A. The types of uredinial infection produced by *P. graminis avenae*, forms 1, 2, 3, 4 and 5, on Jcanette Strain in the mature stage when kept at a temperature of 24°C. Left to right: Two stems of Joanette Strain infected by forms 1, 2, 3, 4 and 5, respectively.

Figure B. The types of uredinial infection produced by *P. graminis avenae*, forms 1, 2, 3, 4 and 5, on Joanette Strain in the mature stage when kept at a temperature of 28°C. Left to right: Two stems of Joanette Strain infected by forms 1, 2, 3, 4 and 5, respectively.

EXPERIMENTAL METHODS AND MATERIALS

The methods employed in the study of the relation of environment to the uredinial and telial development of the physiologic forms varied according to the object of the individual experiments. The more general methods used will be stated here, while those of a more specific nature will be given in connection with the different experiments.

The nine physiologic forms of *P. graminis avenae* employed in the various experiments were isolated from collections of oat stem rust made in Canada during the period 1925-1930 (Table 3). The types of infection produced by the nine forms on the hosts, Victory, White Russian, Richland and Joanette Strain, in the seedling stage, are illustrated in Plates I - III. In certain experiments cultures of forms 6 and 7, yellow in colour, were also used. The colour of these cultures, according to Ridgway's Colour Standards (40, Plate 15), is "ochraceous orange", while that of normal oat stem rust (40, Plate 3), is "amber brown". These two cultures will be referred to as 6Y and 7Y. They were obtained from a barberry which had been artificially inoculated in the spring of 1931 with teliospore material which had been gathered from the field plots at Winnipeg, Man., during the autumn of 1930.

One or more of the hosts, Victory, White Russian, Richland and Joanette Strain, were used throughout the study. Victory is susceptible to all the forms, while the other hosts are differential in their reaction. These varieties of oats were employed first by Bailey (*1*) in studies on physiologic specialization in *P. graminis avenae.*

The classes of host reaction as well as the infection types employed by Bailey (*1*) were adopted. These are given in Table 4.

TABLE 4.—CLASSES OF HOST REACTION AND TYPES OF RUST INFECTION.

Classes of Host Reaction	Types of Rust Infection
Practically immune.	0. No uredinia developed, but sharply defined hypersensitive flecks present.
Extremely resistant.	1. Infection very light; uredinia minute, scattered, and surrounded by sharply defined necrotic areas.
Moderately resistant.	2. Infection light; uredinia usually small and scattered, hypersensitive areas varying from sharply defined necrosis to pronounced chlorosis.
Moderately susceptible.	3. Infection moderate; uredinia mid-sized with a tendency to coalesce; true hypersensitiveness absent, but more or less well marked chlorosis present.
Completely susceptible.	4. Infection normal and heavy; uredinia large, numerous and confluent; hypersensitiveness absent, but chlorosis may be present.
Indeterminate.	X. Uredinia very variable, apparently including all types of infection, often on the same leaf blade; no mechanical separation of the types seems possible, and the infection is ill-defined and heterogeneous.

The symbols (=), (−), (±), and (+) indicate quantitative variations in the types of uredinial infection. A semicolon (;) when used indicates the presence of flecks. The letters (cn) denote that hypersensitiveness ranging from chlorosis to necrosis accompanies the infection.

TABLE 5.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY SEVEN PHYSIOLOGIC FORMS ON SEEDLINGS OF FOUR HOSTS KEPT AT TWO TEMPERATURES.

Forms	Hosts	Temperatures					
		14°C.			26°C.		
		Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	Victory	11/11(4)	16/16(4)	13/13(4)±	10/10(4)+	10/10(4)±	10/10(4)+
	White Russian	11/11(3)c̄	10/10(3)c̄	10/10(3)c̄	12/12(3)c̄	12/12(3)c̄n	16/16(3)c̄
	Richland	13/13(2)=	14/14(2)=	14/14(2)	13/13(2)–	10/10(2)–	14/14(2)–
	Joanette Strain	8(1)– ; 3 / 12	9(1)= 1(x)= / 10	9(1)– ; 4 / 13	11/11(4)	6(4)–14(3)cn + / 20	12/12(4)c ±
2	Victory	12/12(4)	11/11(4)–	11/11(4)+	15/15(4)+	10/10(4)+	13/13(4)
	White Russian	7/7(3)c̄	10/10(3)c̄	13/13(3)c̄	13/13(3)c̄	19/19(3)c̄	11/11(3)c̄
	Richland	9/9(2)=	10/10(2)–	15/15(2)	8/8(2)–	9/9(2)	12/12(2)–
	Joanette Strain	12/12(4)	10/10(4)	10/10(4)	9/9(4)+	12/12(4)+	10/10(4)–
3	Victory	9/9(4)	10/10(4)	11/11(4)+	14/14(4)+	10/10(4)+	10/10(4)
	White Russian	7/7(4)	10/10(4)	18/18(4)	11/11(4)	10/10(4)	10/10(4)
	Richland	11/11(2)–	10/10(2)–	22/22(2)	13/13(2)–	10/10(2)–	13/13(2)–
	Joanette Strain	10(1)=; 7 / 17	3(1)=; 6 / 10	10/10(1)=	14/14(4)c ±	10/10(4)c̄	12/12(4)c̄n
4	Victory	13/13(4)	10/10(4)±	10/10(4)+	12/12(4)+	10/(10)±	10/10(4)+
	White Russian	11/11(4)	8/8(4)±	19/19(4)	14/14(4)	10/10(4)±	10/10(4)–
	Richland	9/9(4)	8/8(4)±	14/14(4)	10/10(4)+	10/10(4)±	17/17(4)±
	Joanette Strain	1(x)=8(1)± / 9	10/10(1)–	2(x)=8(1)– / 10	14/14(4)±	10/10(4)c	10/10(4)c̄n
5	Victory	14/14(4)	13/13(4)	13/13(4)	16/16(4)±	11/11(4)–	12/12(4)
	White Russian	13/13(3)c̄ =	12/12(3)c	10/10(3)c	16/16(3)c̄ =	18/18(3)c	12/12(3)c
	Richland	19/19(2)=	14/14(2)–	10/10(2)	15/15(2)–	15/15(2)–	11/11(2)–
	Joanette Strain	12(1)±1(x)– / 13	7(1)-3(x)= / 10	9(1)–2(x)-; / 11	11/11(4)–	15/15(4)c	12/12(4)c̄
6	Victory	7/7(4)	8/8(4)±	10/10(4)+	14/14(4)+	12/12(4)±	12/12(4)±
	White Russian	8/8(4)	10/10(4)	13/13(4)	13/13(4)	14/14(4)	10/10(4)
	Richland	11/11(4)	15/15(4)+	10/10(4)+	10/10(4)+	16/16(4)±	16/16(4)±
	Joanette Strain	8/8(4)c̄	12/12(4)c	12/12(4)±	12/12(4)+	15/15(4)	12/12(4)
7	Victory	13/13(4)	16/16(4)±	10/10(4)±	12/12(4)	10/10(4)±	11/11(4)+
	White Russian	10/10(4)	17/17(4)	16/16(4)±	10/10(4)–	10/10(4)	15/15(4)
	Richland	9/9(2)–	16/16(2)–	10/10(2)–	9/9(2)=	11/11(2)=	10/10(2)
	Joanette Strain	12/12(4)	18/18(4)±	12/12(4)±	19/19(4)–	13/13(4)±	14/14(4)+

The method of recording results of inoculations is as follows. The types of infection are enclosed in brackets. The figures preceding the types of infection indicate the number of plants infected, e.g., 8/10(4) shows that eight out of ten plants inoculated became infected and the type of infection produced on them was (4)–. A record of inoculation, such as $\frac{2(1)\ 3(2)\ ;\ 5}{10}$, indicates that out of ten plants inoculated, the (1) type of infection was produced on two plants; the (2) type on three plants; and the ; 5 shows that only flecks occurred on five plants.

For the inoculation of the plants, a standard procedure was followed throughout this study. After thoroughly washing the hands, the bloom was removed from the leaves, or stems, of the plants by rubbing them lightly. The plants were then sprayed with water by means of an atomizer, and urediniospores of the desired physiologic form were applied with the thumb and forefinger. The hands were again thoroughly washed before another physiologic form was used. This method of applying the urediniospores to the plants, instead of using an inoculating needle of the type generally used in rust culture work, had the advantage of greater speed and was equally as efficient as the other.

After inoculation, the pots of plants were labelled and placed in incubation chambers for a period of 48 hours to allow infection to take place. The incubation chambers consist essentially of a galvanized iron cylinder with a glass top which stands inside a galvanized iron tray having a shallow rim. Water placed in the tray keeps the atmospheric humidity sufficiently high in the chamber to permit excellent infection. At Madison, the inoculated plants were kept for 48 hours in large incubation chambers in which the atmospheric humidity and temperature could be controlled. In the studies carried on at Winnipeg, after the pots of plants were kept for 48 hours in the incubation chambers, they were removed and placed on benches in the desired sections of a greenhouse. The space on the benches was divided into compartments by glass partitions.

In the various studies upon the effect of temperature on the uredinial and telial development of the physiologic forms the experimental conditions were as follows. At Winnipeg, two sections of a greenhouse were equipped with temperature control apparatus. One section was maintained at a relatively low, the other at a relatively high temperature. In both sections, fluctuations from the mean temperature were limited to approximately 2°C. Temperature was the only environmental factor under control in these sections of the greenhouse. The conditions of light, atmospheric humidity, etc., were subject to considerable variation but were essentially the same in both sections. Artificial lighting, when found to be desirable, was available in both sections to supplement daylight. At Madison, the various studies were carried on in four glass chambers in which the atmospheric humidity, as well as the temperature was controlled. The four chambers were located in separate sections of a greenhouse in which the temperature could also be regulated. The chambers were maintained at temperatures of 12°, 16°, 24°

and 28°C. In the studies dealing with temperature, the relative atmospheric humidity was maintained at 75% in the different chambers. Artificial lighting, when necessary, was used in the four chambers to supplement daylight.

The various experiments carried on at Winnipeg, or at Madison, will be designated accordingly.

The Relation of Temperature to the Uredinial and Telial Development of the Physiologic Forms

Effect of Temperature on Uredinial Development

Review of Literature

That temperature influences the development of cereal rusts has been observed by numerous workers (3, 8, 9, 17, 20, 26, 29, 44, 52, 53). Their observations or investigations dealt largely, however, with the effect of temperature on the germination of the urediniospores and on the duration of the incubation period. The effect of the environment upon the later uredinial development has been investigated also. Gassner (*12*) found that in South America the various cereal rusts were affected differently by environmental conditions. New uredinial infections by *Puccinia triticina* Erikss. and *Puccinia coronifera* Kleb. occurred at all seasons of the year, while infections by *Puccinia graminis* Pers. appeared to be more or less limited to early summer and autumn. Temperature, as a variable factor of the environment, may be considered to have had some influence on the spread of the rusts. Stakman and Lambert (*46*), in considering the causes of stem rust epidemics in the spring wheat area of the United States, expressed the opinion that temperature is one of the important variables in the environment which determines whether or not epidemics will develop. The results of their investigations showed that there was a tendency for destructive epidemics to develop in warm growing seasons and for relatively light infection to occur in cool seasons.

The identification and separation of physiologic forms in the cereal rusts is based upon the types of uredinial infection produced by the different forms on a number of differential hosts. The reactions of these hosts to the various physiologic forms were considered to be practically constant. Although it was recognized that environmental conditions were capable of producing slight variations in the host reactions, it was not considered that these variations could be sufficiently marked to present any serious obstacle to the separation and identification of the various physiologic forms. As the result of a study of the constancy of host reactions to *Puccinia graminis tritici-compacti*, Stakman *et al.* (*43*) state, "The facts recorded in this paper, supported by experimental work in the rust nursery and by field investigations, indicate that rust resistance is comparable with other permanent characters, and that it is not primarily controlled by seasonal conditions, soil type, geographical location, or other cultural conditions. It is rather an hereditary character, which cannot be produced by the accumulation of fluctuating variations within a susceptible line, nor broken down by changes in the host or parasite". Peltier (*35*) also came to the conclusion from the results of a study of the effects of temperature upon host reactions to *P.*

graminis tritici, forms 3 and 9, that the host reactions were not appreciably influenced by the environmental factor, temperature. In other words, the infection types produced by these physiologic forms on a number of hosts were not significantly different at various temperatures. However, the fact that environmental conditions are capable of inducing striking changes in the reactions of differential hosts to physiologic forms of different cereal rusts has been clearly demonstrated in recent years.

Waterhouse (*54*), in 1929, found that variations in environmental conditions in the greenhouse influenced profoundly the reactions of differential hosts to various rusts. In the case of *P. graminis tritici*, there was a change from complete susceptibility of certain hosts in the hotter months to complete resistance in the cooler months of the year. The reactions of several differential hosts showed this change. Some physiologic forms showed more striking alterations of this nature than others. Observations on three physiologic forms of *P. graminis avenae* revealed the same situation. When the temperature in the greenhouse was high, one of the differential hosts, Joanette Strain, was completely susceptible to form 1; when low, it was completely resistant. Only this differential host showed a change in reaction due to a change in temperature. The types of infection produced by forms 2 and 7 on all differential hosts, however, were not significantly changed. Essentially similar results were obtained with *P. triticina* and *P. simplex* (Korn.) Erikss. and Henn., that is, some hosts were susceptible at a high temperature while at a low tenperature they were resistant. The significance of these results to studies of physiologic forms in the cereal rusts has led to further investigations of the problem by other workers.

In 1930, Gordon (*15*) reported the results of a preliminary study on the effect of temperature upon host reactions to eight physiologic forms of *P. graminis avenae*. This study was carried out in sections of a greenhouse which were maintained at approximately constant temperatures. The results obtained showed that the reaction of the differential host, Joanette Strain to forms 1, 3, 4 and 5 at a low (57.4°F.) and at a high temperature (75.4°F.) were strikingly different. This host was susceptible to forms 1, 3, 4, and 5 at the high temperature but was resistant to forms 1, 3 and 4, and indeterminate in its reaction to form 5, at the low temperature. There was no significant difference in the reactions of the hosts Victory, White Russian and Richland to these forms when kept at different temperatures. The types of infection produced by forms 2, 6, 7 and 8 on the four hosts, Victory, White Russian, Richland and Joanette Strain, were not affected by different temperatures.

Peturson (*36*), in 1930, first showed that temperature influenced the types of infection produced by physiologic forms of *Puccinia coronata avenae* (Corda) Erikss. and Henn. on certain differential hosts. One host, Red Rustproof, was susceptible to form 4 at temperatures of 70° and 77°F., but resistant at 57°F. All the differential hosts were susceptible to form 7 at a temperature of 77°F. but some were resistant at 57°F. The types of infection produced by forms 1 and 3 on all hosts were not influenced by differences in temperature.

In 1931, Gassner and Straib (*13*) reported the results of their investigation on the effect of temperature on the constancy of the infection types produced by *P. triticina* on a number of wheat varieties generally considered to be very resistant. A definite increase in the susceptibility of certain varieties occurred at the lowest temperature employed (6°C.).

Johnson (*24*) studied the behaviour of several physiologic forms of *P. graminis tritici* characterized by the (X), or heterogeneous, type of infection on certain wheat varieties at low (55° - 60°F.) and high temperatures (70° - 75°F.). The behaviour of these forms on hosts which were normally indeterminate in their reaction was strikingly different at the two temperatures. The (X) type of infection did not appear at either of these temperatures. At the low temperature, the hosts were highly resistant, and, at the high temperature, they were quite susceptible.

Newton *et al* (*32*) found that low temperatures appear to favour the optimum development of the uredinial stage of *P. glumarum*. At a temperature of 64°F., such varieties as Chul, Mindum and Kanred were highly susceptible and abundant pustules were developed on them, while at 70°F. they became highly resistant, only flecks being produced.

In Germany, Hey (*19*) determined the types of uredinial infection produced by eight physiologic forms of *P. simplex* on ten standard varieties of barley at temperatures of 10°, 18°. 25° and 30°C. Significant differences in the types of uredinial infection produced by some forms on certain varieties were found to occur at the different temperatures.

Melander (*30*) found that form 35 of *P. graminis tritici* produced only minute uredinia on Little Club wheat after it was kept fifty-nine days at a temperature of 0 - 1°C.

The effect of temperature on the expression of factors governing rust reaction in a cross between Marquillo and Marquis wheat was reported by Harrington (*16*) in 1931. Two random populations of F_2 plants of this cross were tested for the reaction of their F_3 seedling progenies to form 21 of *P. graminis tritici* in the greenhouse at average daily temperatures of 69.7° for one population, and 60.6°F. for the other. At 69.7°F. ten families of a total of 781 were resistant; at 60.6°F. five families of a total of 301 were susceptible.

THE UREDINIAL DEVELOPMENT OF SEVEN PHYSIOLOGIC FORMS AT TWO TEMPERATURES (WINNIPEG)

The object of this experiment was to determine the effect of temperature upon the uredinial development of physiologic forms 1, 2, 3, 4, 5, 6 and 7, on the hosts, Victory, White Russian, Richland and Joanette Strain. The classification of the forms mentioned is based upon the types of infection which they produce on the hosts White Russian, Richland and Joanette Strain (Table 2). If these infection types are capable of being altered by temperature, it is obvious that errors in identification are liable to occur.

The procedure followed during each of three trials was to inoculate two sets of seedlings of the hosts mentioned with urediniospores of each physiologic form. Prior to inoculation, the hosts were grown in the greenhouse under the same environmental conditions. After being kept for 48 hours following

inoculation in the incubation chambers, one set of hosts was placed in each of the temperature-controlled sections of the greenhouse until observations on the complete uredinial development of the different forms were recorded. One section of the greenhouse was maintained at a low (14°C.), the other ay a high temperature (26°C.).

The first effect of temperature upon the uredinial development of the various forms to be observed was that, while the incubation period at 26°C. was 7 days, at 14°C. it was extended to 12 days.

The types of uredinial infection produced by the seven physiologic forms on the four hosts kept at 14°C. and at a temperature of 26°C., are shown in Table 5. There was no significant difference in the types of infection produced by forms 2, 6 and 7 on any of the hosts at the two temperatures. Temperature apparently did not influence the complete uredinial development of these forms on the hosts used. However, the complete uredinial development of forms 1, 3, 4, and 5 was strikingly different on the differential host Joanette Strain, at the low and high temperatures, but was not appreciably different on the other hosts. Joanette Strain was quite susceptible to these four forms at 26°C. but much more resistant at a temperature of 14°C. The high temperature apparently favoured the uredinial development of these forms on Joanette Strain, while the low temperature inhibited their growth.

This preliminary experiment on the effect of temperature upon the uredinial development of the physiologic forms was carried on during February, 1931. At this time only seven physiologic forms were available for study. All the known physiologic forms of *P. graminis avenae* were used in a much more extensive experiment carried on at Madison during the autumn of 1931.

THE UREDINIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS AT FOUR TEMPERATURES (MADISON)

In this experiment, the nine physiologic forms known to occur in *P. graminis avenae* were available for study. Forms 6Y and 7Y, yellow in colour, were also included. The uredinial development of all the forms on the hosts Victory, White Russian, Richland and Joanette Strain was determined at temperatures of 12°, 16°, 24° and 28°C. The procedure followed during each of three trials was to inoculate the eight sets of the hosts in the seedling stage with urediniospores of each physiologic form. Prior to inoculation the hosts were grown under the same environmental conditions. Two sets of the hosts inoculated with each form were placed in temerature-controlled chambers maintained at temperatures of 12°, 16°, 24° and 28°C. The hosts were kept in the chambers during the complete development of the uredinial stage of the various physiologic forms.

The development of the hosts was markedly different at the low (12° and 16°C.) and at the high temperatures (24° and 28°C.). At 12° and 16°C., the plants grew slowly but were quite healthy in appearance, while at temperatures of 24° and 28°C., particularly at 28°C., it was quite evident that the environmental conditions were distinctly unfavourable for their growth. Practically all plants showed considerable chlorosis and some died before the complete development of the uredinia upon them could be attained.

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TABLE 6.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY NINE PHYSIOLOGIC FORMS ON SEEDLINGS OF FOUR HOSTS KEPT AT FOUR TEMPERATURES.

Forms	Hosts	Tenperatures			
		12°C.	16°C.	24°C.	28°C.
1	Victory	70/70(4)–	69/69(4)±	72/73(4)±c	66/75(4)±cn
	White Russian	87/87(3)=c	80/80(3)–c	83/88(3)–c	67/80(3)–cn
	Richland	70/70(2)–	80/80(2)–	87/88(2)–	75/82(2)=cn
	Joanette Strain	20(1)14(x)=; 56 / 90	55(1)±30(x)=; 6 / 91	16(x)+61(4)±c / 80	86/94(4)+cn =
2	Victory	64/64(4)	70/70(4)±	61/61(4)c	73/77(4)±cn
	White Russian	62/63(3)–c	74/75(3)–c	58/62(3)–c	66/78(3)=cn
	Richland	79/80(2)–	66/66(2)–	54/57(2)–	64/79(2)–cn
	Joanette Strain	66/66(4)–c	79/81(4)±	74/75(4)c	67/74(4)±cn
3	Victory	84/84(4)–	73/73(4)	62/68(4)c	63/70(4)+cn =
	White Russian	90/92(4)–	79/80(4)	64/65(4)±c	69/75(4)+cn =
	Richland	80/83(2)–	62/66(2)	83/90(2)–c	61/73(2)=cn
	Joanette Strain	11(1)±; 82 / 95	37(1)±6(x)=; 38 / 81	9(x)+82(4)c / 94	67/77(4)+cn =
4	Victory	70/70(4)–	60/60(4)	61/64(4)±cn	68/79(4)±cn
	White Russian	52/52(4)–	75/77(4)	58/61(4)c	69/79(4)+cn =
	Richland	77/79(4)–	80/81(4)	81/83(4)±c	70/79(4)±cn
	Joanette Strain	14(1)±6(x)=; 54 / 78	48(1)±17(x)=;14 / 80	9(x)+71(4)c / 80	67/79(4)±cn
5	Victory	75/75(4)–	75/75(4)±	82/82(4)±cn	75/82(4)+cn =
	White Russian	77/84(3)–c	82/83(3)–c	81/84(3)–c	70/79(3)=cn
	Richland	81/82(2)–	75/78(2)–	86/88(2)–cn	69/81(2)=cn
	Joanette Strain	34(1)±12(x)=;45 / 95	46(1)32(x)–; 3 / 81	20(x)+c62(4)±c / 87	72/84(4)+cn =
6	Victory	55/55(4)–	47/50(4)	39/40(4)c	55/58(4)±cn
	White Russian	50/51(4)–	53/54(4)–	42/42(4)–c	46/53(4)+cn =
	Richland	53/54(4)	53/54(4)	40/41(4)	46/55(4)±cn
	Joanette Strain	58/59(4)–	50/50(4)	52/52(4)c	48/52(4)+cn =

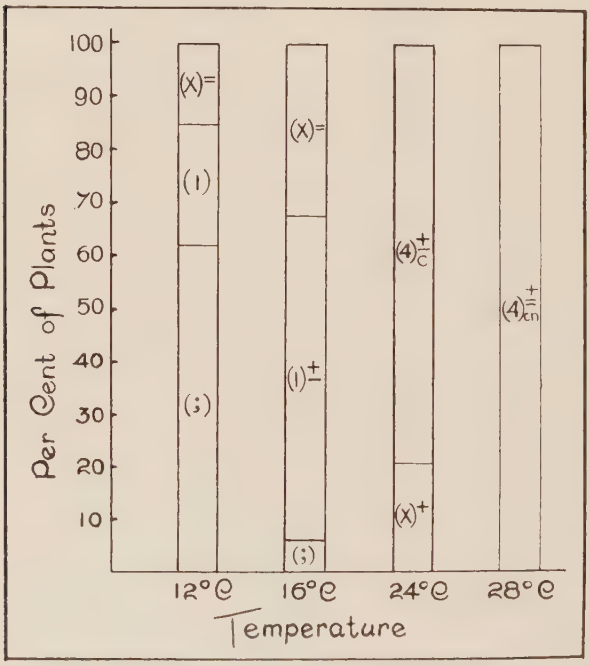
TABLE 6.—*Continued*

Forms	Hosts	Temperatures			
		12°C.	16°C.	24°C.	28°C.
7	Victory	43/43(4)–	56/56(4)	45/45(4)c	43/51(4)±cn
	White Russian	53/53(4)–	54/55(4)	48/51(4)c	44/53(4)+cn
	Richland	47/50(2)–	50/51(2)–	49/55(2)–	43/52(2)=cn
	Joanette Strain	53/55(4)–	52/54(4)	48/51(4)±c	44/51(4)±cn
8	Victory	46/48(4)	47/47(4)	51/53(4)±c	42/52(4)±cn
	White Russian	52/53(3)=c	50/52(3)–c	44/48(3)–c	41/49(3)=cn
	Richland	58/61(4)	53/56(4)	52/55(4)c	43/48(4)+cn
	Joanette Strain	55/56(4)	47/47(4)	51/52(4)c	46/51(4)±cn
9	Victory	61/62(4)–	54/54(4)	45/47(4)±c	49/59(4)±cn
	White Russian	53/54(3)–c	52/53(3)–c	48/51(3)–c	49/55(3)–cn
	Richland	54/55(3)–c	53/54(3)–c	51/52(3)c	43/51(3)±cn
	Joanette Strain	52/54(4)–	54/54(4)	54/56(4)c	42/49(4)±cn
6Y	Victory	50/50(4)–	55/55(4)	46/49(4)±c	44/53(4)±cn
	White Russian	49/49(4)–	51/52(4)–	46/50(4)±c	48/56(4)+cn
	Richland	55/56(4)	54/55(4)	52/54(4)±c	54/62(4)±cn
	Joanette Strain	59/61(4)–	52/54(4)	56/59(4)c	55/62(4)+cn
7Y	Victory	60/61(4)	54/54(4)	48/52(4)±c	43/55(4)±cn
	White Russian	57/58(4)–	47/48(4)	54/54(4)±c	53/59(4)+cn
	Richland	54/56(2)–	46/46(2)–	51/58(2)=c	40/56(2)±cn
	Joanette Strain	51/51(4)	47/47(4)	53/56(4)±c	49/56(4)±cn

The first effect of the different temperatures to be observed upon the uredinial development of the various forms was the difference in length of the incubation periods at the four temperatures. At 12°C., the length of the incubation period amounted to 16 days; at 16°C., 12 days; at 24°C., 8 days; and at 28°C., 9 days. The shortest period of incubation occurred at 24°C. It was greatly extended at the temperatures below, and slightly so at the temperatures above this one.

With regard to the complete development of the uredinial stage of the various forms at the four temperatures, it was again found that temperature

profoundly influenced the development of certain forms. The complete uredinial development of the various physiologic forms at the four temperatures, as expressed by the types of infection produced by them on the different hosts, is shown in Table 6. Only minor variations occurred in the types of infection produced by forms 2, 6, 7, 8 and 9 on all the hosts at the four temperatures. Similarly, only slight variations were observed in the types of infection produced by forms 1, 3, 4 and 5 on Victory, White Russian and Richland at the different temperatures. However, the types of uredinial infection produced by these four forms on Joanette Strain were markedly changed by temperature. Photographs illustrating the types of uredinial infection produced by forms 1, 3, 4 and 5 on Joanette Strain are presented in Plates III and IV. The uredinial development of form 2 on this host is shown in Plate IV by way of comparison with that of forms 1, 3, 4 and 5. The uredinial development of this form on Joanette Strain at the four different temperatures is typical of the physiologic forms which are not appreciably affected by temperature.



Text Figure 4. A graph illustrating the percentage of seedlings of Joanette Strain on which the types of infection indicated were produced by form 1 at four temperatures. At 12°C., (;) were produced on approximately 60%, (1) on 25% and (x)= on 15% of the seedlings. At 16°C., (;) were produced on approximately 5%, (1) ± on 65% and (x)= on 30%. At 24°C., (x)+ was produced on approximately 20% and (4)±c on 80%. At 28°C., (4)±cn was produced on 100% of the seedlings.

The most extensive uredinial development of forms 1, 3, 4 and 5 occured on Joanette Strain at 28°C., while the least was at a temperature of 12°C. Their uredinial development on this host at 16°C. was slightly greater than that at 12°C.,; at 24°C., it resembled quite closely that which occurred at 28°C. The difference in the uredinial development of form 1 on Joanette Strain at the four temperatures is shown graphically in Text Figure 4. The number of Plants on which each type of infection was produced is expressed as a percentage of the total number of infected plants. Similar differences in the uredinial development of forms 3, 4 and 5 on Joanette Strain occurred at the four temperatures.

Of the nine physiologic forms of *P. graminis avenae*, in only four of them, forms 1, 3, 4 and 5, did the uredinial development appear capable of being appreciably changed by temperature.

TABLE 7.—THE TYP ES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 2, 3, 4, AND 5 ON SEEDLINGS OF FOUR HOSTS KEPT AT DIFFERENT TEMPERATURES.

Forms	Hosts	Temperatures	
		12°C. before and 28°C. after inoculation	12°C. before and after inoculation
1	Victory	32/32(4) ± c	31/31(4)–
	White Russian	33/33(3)–c	35/35(3)–c
	Richland	33/34(2)–	32/32(2)–
	Joanette Strain	34/35(4) ± cn	4(1) – ; 30 / 34
2	Victory	31/32(4) ± cn	30/30(4)–
	White Russian	32/32(3)–cn	36/36(3)–c
	Richland	31/33(2)–	30/30(2)–
	Joanette Strain	32/33(4) ± c	31/31(4)–
3	Victory	37/37(4) ± cn	32/32(4)–
	White Russian	33/33(4)c	33/33(4)–
	Richland	31/32(2)–	31/31(2)–
	Joanette Strain	32/33(4) ± cn	2(1) – ; 33 / 35
4	Victory	31/31(4) ± c	30/30(4)–
	White Russian	33/34(4)cn	31/31(4)–
	Richland	37/37(4) ± cn	32/33(4)–c
	Joanette Strain	32/33(4) ± cn	11(1) ; 20 / 31
5	Victory	34/34(4) ± cn	31/31(4)–
	White Russian	37/38(3)–cn	33/33(3)–cn
	Richland	30/31(2)–	36/37(2)–
	Joanette Strain	33/34(4) ± c	12(1)–2(x) = ; 17 / 31

THE UREDINIAL DEVELOPMENT OF FIVE PHYSIOLOGIC FORMS ON HOSTS KEPT PRIOR TO INOCULATION AT A LOW (12°C.) AND ALSO AT A HIGH (28°C.) TEMPERATURE (MADISON)

That the uredinial development of certain physiologic forms is influenced by the temperature at which the hosts are kept after inoculation was demonstrated by the previous experiments. The possibility existed that their uredinial development might also be influenced by the temperature at which

TABLE 8.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 2, 3, 4 AND 5 ON SEEDLINGS OF FOUR HOSTS KEPT AT DIFFERENT TEMPERATURES.

Forms	Hosts	Temperatures	
		28°C. before and 12°C. after inoculation	28°C. before and after inoculation
1	Victory	34/34(4)–	31/31(4) ± c
	White Russian	37/37(3)–c	36/37(3)–c
	Richland	31/31(2)–	30/30(2)–
	Joanette Strain	10(1)– ; 21 / 31	33/34(4) ± cn
2	Victory	28/28(4)–	30/30(4) ± c
	White Russian	31/32(3)–	33/34(3)–c
	Richland	30/31(2)–	32/34(2)–
	Joanette Strain	36/36(4)–	28/28(4) ±
3	Victory	29/29(4)–	31/31(4) ± cn
	White Russian	30/30(4)–c	31/33(4)c
	Richland	27/27(2)–	34/35(2)–
	Joanette Strain	7(1) – ; 31 / 38	32/34(4) ± cn
4	Victory	30/30(4)–	32/32(4) ± c
	White Russian	34/35(4)–	27/27(4)cn
	Richland	31/31(4)–	30/32(4) ± c
	Joanette Strain	8(1) – ; 25 / 33	34/36(4) ± cn
5	Victory	28/28(4)–	34/34(4) ± c
	White Russian	30/30(3)–c	30/31(3)–c
	Richland	33/33(2)–	28/30(2)–
	Joanette Strain	20(1) – 1(x) = ; 7 / 30	31/31(4) ± cn

the hosts were grown prior to inoculation. An experiment was undertaken to determine what effect there would be on the uredinial development of forms 1, 2, 3, 4 and 5, on the hosts Victory, White Russian, Richland and Joanette Strain in the seedling stage if these varieties were grown, prior to inoculation, at a low (12°C.) and at a high temperature (28°C.). After the hosts grown at 12°C. were inoculated with the various physiologic forms, half were transferred to a chamber maintained at a temperature of 28°C.,

and the remainder were retained in the chamber at 12°C.; half of the hosts grown prior to inoculation at 28°C. were transferred after inoculation to a chamber kept at a temperature of 12°C., and the remainder were retained in the chamber at 28°C. The chambers maintained at a temperature of 12°C. and at 28°C., were both kept at a relative atmospheric humidity of 75%.

The results of this experiment which are given in Tables 7 and 8, show that the uredinial development of forms 1, 2, 3, 4 and 5 on Victory, White Russian, Richland and Joanette Strain were not appreciably influenced by the temperature at which the hosts were grown prior to inoculation. There was no significant difference in the uredinial development of the various forms whether the hosts were kept at 12°C. both before and after inoculation, or kept at 28°C. before inoculation, and at a temperature of 12°C. afterward. Similarly, there was no significant difference in their uredinial development whether the hosts were kept at 28°C. both before and after inoculation, or kept at 12°C. before, and at a temperature of 28°C. after they were inoculated.

From the results of this experiment, it appears that the temperature at which hosts in the seedling stage are kept prior to inoculation has no appreciable effect upon the uredinial development of the physiologic forms of *P. graminis avenae.* The type of uredinial infection produced by forms 1, 3, 4 and 5 on Joanette Strain, however, is profoundly influenced by the temperature at which this host is kept after inoculation.

THE UREDINIAL DEVELOPMENT OF FORMS 1, 3, 4 AND 5 ON THE HOST JOANETTE STRAIN WHEN KEPT FOR DIFFERENT LENGTHS OF TIME AFTER INOCULATION AT A TEMPERATURE OF 12°C. AND AT 28°C. (MADISON)

The object of this experiment was to ascertain the effect on the uredinial development of forms 1, 3, 4 and 5 on Joanette Strain in the seedling stage when kept for different lengths of time after inoculation at 12°C., and then transferred to a temperature of 28°C., and also when kept for different lengths of time at 28°C., and then transferred to a temperature of 12°C.

Forty-four pots of seedlings of Joanette Strain were inoculated with each of the four physiologic forms. After inoculation, they were kept as usual for 48 hours in incubation chambers to allow infection to take place. The temperature within the incubation chambers was maintained at approximately 20°C. On removal from the incubation chambers, 22 pots of seedlings inoculated with each form were placed in the temperature-controlled chamber maintained at 12°C., and 22 in the chamber at 28°C. After one day, and on each succeeding day for ten days, two pots were transferred from the low (12°C.) to the high temperature (28°C.), and two from the high (28°C.) to the low temperature (12°C.). Two pots were kept continuously at each temperature as checks.

The uredinial development of the four physiologic forms, expressed as the types of infection produced by them on Joanette Strain, is shown in Tables 9 and 10. The uredinial development of the four forms on Joanette Strain, when kept from one to six days after inoculation at 12°C. before being transferred to a temperature of 28°C., was essentially the same as that which occurred on this host when kept continuously at 28°C. That is, it attained its maximum development. However, when this host was kept for a longer period than six days at 12°C. before being transferred to a temperature of

TABLE 9.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 3, 4 AND 5 ON SEEDLINGS OF JOANETTE STRAIN WHEN KEPT FOR DIFFERENT LENGTHS OF TIME AT 12°C. AND THEN TRANSFERRED TO A TEMPERATURE OF 28°C.

No. of days at 12°C.	Physiologic forms			
	1	3	4	5
1	30/30(4)±c	31/31(4)±c	33/33(4)±c	31/31(4)±c
2	36/36(4)±c	32/33(4)±c	34/34(4)±c	32/32(4)±c
3	33/33(4)c	38/38(4)±c	31/31(4)c	36/36(4)
4	30/30(4)c	33/33(4)±c	39/39(4)±c	37/37(4)±c
5	31/32(4)c̄	37/38(4)c̄	36/37(4)	31/32(4)c̄
6	35/35(4)c̄	33/33(4)c̄	38/39(4)c̄	36/36(4)c̄
7	14(4) – 20(x)+ / 34	11(x)20(4) / 31	21(x) 14 (4)– / 35	24(x) 11 (4)– / 35
8	31/31(x)±	38/38(x)±	34/35(x)	38/38(x)–
9	5(1) 2 (x) ; 30 / 37	3(1) 2 (x) – ; 30 / 35	8(1) 4 (x)– ; 22 / 34	2(1) 6 (x) ; 24 / 32
10	4(1) ; 31 / 35	3(1) ; 30 / 33	2(1) ; 32 / 34	6(1) 1 (x) = ; 30 / 37
Kept continuously at 28°C.	34/35(4)±cn	34(4)±cn	30/30(4)±c	33/33(4)±c

TABLE 10.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 3, 4 AND 5 ON SEEDLINGS OF JOANETTE STRAIN WHEN KEPT FOR DIFFERENT LENGTHS OF TIME AT 28°C. AND THEN TRANSFERRED TO A TEMPERATURE OF 12°C.

No. of days at 28°C.	Physiologic forms			
	1	3	4	5
1	4(1) ; 30 / 34	3(1) ; 29 / 32	2(1) ; 31 / 33	7(1)± ; 23 / 31
2	10(1)±15(x)=;6 / 31	20(1)±1(x)=;10 / 35	4(1)±28(x)=;3 / 35	2(1) 29 (x)= / 31
3	37/37(x)–	2(1)±31(x)– / 33	36/36(x)–	39/39(x)–
4	36(x)+2(4) / 38	31(x)c 3(4) / 34	34(x)+2(4) / 36	33(x)c5(4) / 38
5	31(4)c5(x) / 36	6(x)31(4) / 37	2(x)31(4)c / 34	1(x)37(4)c / 38
6	31/31(4)c	33/35(4)c	36/37(4)c	35/35(4)c
7	32/32(4)c	36/36(4)c	37/37(4)c	31/31(4)c
8	38/38(4)c	39/39(4)c	37/37(4)c	38/39(4)c
9	37/37(4)	38/38(4)±c	38/38(4)±c	32/33(4)±c
10	39/39(4)±c	33/34(4)+c	39/39(4)+c	36/36(4)c
Kept continuously at 12°C.	5(1) ; 29 / 34	3(1) ; 32 / 35	4(1) ; 32 / 36	7(1)± ; 26 / 35

28°C. the uredinial development was greatly reduced. When retained for ten days at 12°C. before being transferred to a temperature of 28°C., the development of the different forms was in no way different from that which occurred on this host when kept continuously at 12°C.

When this host, after inoculation, was kept first for a number of days at 28°C. before being transferred to a temperature of 12°C., the uredinial development of the four forms was as follows: Kept for one day at 28°C., the uredinial development of the different forms was the same as that at 12°C. for the whole period; kept for a longer time than five days at 28°C., it was the same as that at a temperature of 28°C. for the whole period; kept from two to five days at 28°C., it was intermediate between that produced at a continuous temperature of 12°C. and that at a continuous temperature of 28°C.

THE UREDINIAL DEVELOPMENT OF FORMS 1, 2, 3, 4 and 5 ON JOANETTE STRAIN IN THE SEEDLING AND MATURE STAGES WHEN KEPT DURING THE DAY AT A HIGH (28°C.) AND AT NIGHT AT A LOW (12°C.) TEMPERATURE (MADISON)

In previous experiments, the uredinial development of forms 1, 3, 4 and 5 on Joanette Strain in the seedling stage has been shown to vary widely, depending on the temperature at which this host was kept after inoculation. When kept at a low temperature (12°C.), the uredinial development of these forms was restricted to the production of flecks and a few small pustules but, at a high temperature (28°C.), numerous large pustules were produced. The object of the present experiment was to ascertain the uredinial development of forms 1, 3, 4 and 5 on Joanette Strain in both the seedling and mature stages when kept during the day at a high temperature (28°C.) and during the night at a low temperature (12°C.). This variation in temperature approximates roughly that occurring in the open during the summer and autumn when the temperature during the day is much higher than it is at night.

Although the uredinial development of form 2 has not been shown to vary appreciably due to temperature, it was included in this experiment for comparison with the other physiologic forms.

The procedure followed was to inoculate nine pots of Joanette Strain in the seedling stage and six pots of this host in the mature stage with each of the five forms mentioned. After inoculation, two pots of seedlings and one pot containing mature plants inoculated with each of these physiologic forms were placed as checks in each of two chambers maintained at a low (12°C.) and at a high temperature (28°C.). The check plants were kept continuously at the two respective temperatures. The remaining five pots of seedlings and four of mature plants were kept during the day in the chamber maintained at a temperature of 28°C. and, at night, in the one at 12°C., thus giving them approximately ten hours each day at the high temperature and 14 hours at the low temperature.

In Tables 11 and 12 is shown the uredinial development of the five forms occurring on Joanette Strain kept at the different temperatures. There was no essential difference between the development of each form on the seedlings and mature plants kept at the same temperatures. The uredinial development of forms 1, 3, 4 and 5, when kept during the day at 28°C. and during the night at a temperature of 12°C., was somewhat greater than their uredinial development when kept continuously at a temperature of 12°C., but much

TABLE 11.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 2, 3, 4 AND 5 ON JOANETTE STRAIN IN THE SEEDLING STAGE WHEN KEPT AT DIFFERENT TEMPERATURES

Forms	Temperatures		
	Continuously at 12°C.	28°C. during the day; 12°C. at night	Continuously at 28°C.
1	6(1) ; 20 / 26	26(1) ± 16(x) − ; 17 / 59	26/27(4) ± c
2	24/24(4) −	62/62(4) ± c	27/27(4) ± c
3	2(1) ; 25 / 27	10(1) ± 21(x) − ; 29 / 60	25/25(4) ± c
4	3(1) ; 20 / 23	27(1) ± 21(x) − ; 14 / 62	23/23(4) ± c
5	4(1) 1 (x) = ; 20 / 27	24(1) ± 34(x) − ; 3 / 61	25/25(4) ± c

TABLE 12.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FORMS 1, 2, 3, 4 AND 5 ON JOANETTE STRAIN IN THE MATURE STAGE WHEN KEPT AT DIFFERENT TEMPERATURES.

Forms	Temperatures		
	Continuously at 12°C.	28°C. during the day; 12°C. at night	Continuously at 28°C.
1	3(1) ± ; 2 / 5	7(1) + 9(x) − ; 4 / 20	5/5(4) ± c
2	5/5(4) − c	20/20(4) ± c	5/5(4) ± c
3	4(1) ± ; 1 / 5	10(1) + 6(x) ; 4 / 20	5/5(4) ± c
4	3(1) ; 2 / 5	6(1) ± 9(x) − ; 6 / 21	5/5(4) ± c
5	3(1) 1 (x) = ; 1 / 5	1(1) + ; 19(x) − / 20	6/6(4) ± c

less than that when kept continuously at 28°C. Form 2 attained a similar uredinial development at all temperatures.

THE UREDINIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS ON JOANETTE STRAIN IN THE MATURE STAGE AT FOUR TEMPERATURES (MADISON)

The uredinial development of the nine physiologic forms on Joanette Strain in the seedling stage was investigated at four different temperatures in a previous experiment. Four physiologic forms were found to vary in their uredinial development at these temperatures, while that of the remaining five physiologic forms was essentially the same. The object of this experiment was to ascertain whether the uredinial development of any of the nine forms would vary when Joanette Strain was inoculated in the mature stage and kept at temperatures of 12°, 16°, 24° and 28°C.

The procedure followed during each of three similar trials was to inoculate a number of pots of this host at heading time with urediniospores of each of

TABLE 13.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY NINE PHYSIOLOGIC FORMS ON JOANETTE STRAIN IN THE MATURE STAGE WHEN KEPT AT FOUR DIFFERENT TEMPERATURES.

Forms	Trial No.	Temperatures			
		12°C.	16°C.	24°C.	28°C.
1	1	7(1)±3(x)= / 10	7(1)±3(x)= / 10	+ 8(x)c2(4)c / 10	8/10(4)–cn
	2	5/5(1)±;	5/5(x)=;	5/5(4)c	5/5(4)±cn
	3	5/5(1)±;	3(1)±2(x)= / 5	5/5(4)c	5/5(4)±cn
2	1	9/10(4)±c	10/10(4)±c	10/10(4)±c	9/10(4)±cn
	2	5/5(4)	6/6(4)	± 5/5(4)c	5/5(4)+cn
	3	5/5(4)–	6/6(4)	± 5/5(4)c	5/5(4)–cn
3	1	0/9 ; 7	1(1)+8(x)= / 10	+ 6(x)c3(4)c / 10	10/10(4)–cn
	2	3(1)±; 2 / 6	4(1)±1(x)= / 5	6/6(4)±c	5/5(4)±cn
	3	3(1) ; 2 / 5	5/5(1)±	5/5(4)±c	5/5(4)±cn
4	1	2(1) – ; 7 / 10	8(1)+2(x)= / 10	+ 4(x)c 6(4)c / 10	9/10(4)±cn
	2	2(1) – ; 3 / 5	3(1)±2(x)= / 5	5/5(4)±c	5/5(4)±c
	3	3(1) – ; 2 / 5	2(1)±3(x)= / 5	5/5(4)c	5/5(4)±cn
5	1	3(1)±6(x)– / 9	1(1)±9(x)– / 10	+ 4(x)c6(4)c / 10	9/10(4)cn
	2	2(1)–3(x)= / 5	1(1)+4(x)= / 5	5/5(4)±c	5/5(4)±cn
	3	3(1)–2(x)= / 5	1(1)±4(x)= / 5	5/5(4)±c	5/5(4)±cn
6	1	10/10(4)–c	10/10(4)	9/9(4)c	9/9(4)–cn
	2	6/6(4)–	5/5(4)–	5/5(4)±c	5/5(4)±cn
7	1	10/10(4)	9/9(4)	9/9(4)c	9/10(4)±cn
	2	5/5(4)–	5/5(4)	6/6(4)c	± 5/6(4)cn
8	1	9/9(4)–	10/10(4)	10/10(4)c	10/10(4)–cn
	2	5/5(4)–	5/5(4)	+ 5/5(4)c	5/5(4)±cn
9	1	10/10(4)–	10/10(4)	10/10(4)c	9/10(4)±cn
	2	5/5(4)–	5/5(4)–	+ 5/5(4)c	5/5(4)±cn
6Y	1	9/9(4)–	10/10(4)	10/10(4)c	9/10(4)±cn
	2	5/5(4)–	5/5(4)	5/5(4)c	6/6(4)±cn
7Y	1	10/10(4)–	10/10(4)	+ 10/10(4)c	± 10/10(4)cn
	2	5/5(4)	5/5(4)	5/5(4)c	± 5/5(4)cn

the nine physiologic forms. After the various pots of plants had been kept for the usual length of time in the incubation chambers, one pot of plants inoculated with each physiologic form was placed in each of the four temperature-controlled chambers in the greenhouse maintained at the temperatures just stated.

The uredinial development of the various forms which occurred at the four temperatures is shown in Table 13, and that of forms 1, 2, 3, 4 and 5 is also illustrated in Plates IV and V. Essentially the same results were obtained as when seedlings of Joanette Strain were inoculated. The uredinial development of forms 1, 3, 4 and 5 again varied at the different temperatures, but there was no appreciable difference in that of forms 2, 6, 7, 8 and 9. Temperature, therefore, can be considered to be an important factor in the uredinial development of forms 1, 3, 4 and 5 on Joanette Strain both in the seedling and mature stages. Its influence, however, on the uredinial development of forms 2, 6, 7, 8 and 9 appears to be negligible.

DISCUSSION AND RESULTS

The results of the experiments on the effect of temperature on the uredinial development of the physiologic forms of *P. graminis avenae* substantiate the findings of Waterhouse (*54*) and those obtained by the writer (*15*) in a preliminary study. They are also in agreement generally with those obtained by a number of other workers (*13*, *19*, *24*, *36*) from studies of the effect of temperature on the uredinial development of physiologic forms of other cereal rusts.

Temperature, within the limits employed (12° to 28°C.), does not appear to induce any significant changes in the types of uredinial infection produced by forms 2, 6, 7, 8 and 9 on the hosts Victory, White Russian, Richland and Joanette Strain. In other words, the reactions of these hosts to the physiologic forms mentioned are only subject to minor fluctuations due to variations in temperature. The fluctuations observed in the reactions of White Russian, Richland and Joanette Strain to forms 2, 6, 7, 8 and 9 are not sufficiently great to complicate the correct identification of these forms.

The types of uredinial infection produced also by forms 1, 3, 4 and 5 on the hosts Victory, White Russian and Richland are not significantly different at any of the temperatures employed. That is, the reactions of these hosts to these four physiologic forms are essentially the same at different temperatures. However, the types of uredinial infection produced on the differential host, Joanette Strain, by forms 1, 3, 4 and 5 at relatively low and high temperatures are profoundly different. This host is quite resistant to these four physiologic forms at low temperatures but is completely susceptible at high tempreatures. At high temperatures, it is no longer differential in its reaction to the nine physiologic forms, as it is completely susceptible to all. Only at low temperatures do the forms 1, 3, 4 and 5 produce on Joanette Strain the characteristic types of infection which have hitherto served for their identification on this host. At a relatively high temperature, or when the temperature fluctuates, these physiologic forms do not produce on this host the types of infections which in the past were accepted as characterizing them.

The results of this study are of importance owing to the bearing which they have on the identification of the physiologic forms of *P. graminis avenae*.

It will be apparent that the work dealing with their identification must be carried on in future at relatively low temperatures, if the various forms are to be classified correctly according to the formerly accepted host reactions. This does not appear to be practicable if the physiologic forms present in a large number of oat stem rust collections are to be identified each year. While the temperature in the greenhouse can be controlled fairly accurately during the winter months, it is almost impossible to obtain accurate control during the whole year. Instead of attempting to identify the physiologic forms present in a large number of oat stem rust collections at accurately controlled temperatures, it appears to be more feasible to group the physiologic forms together which only differ from each other in the types of uredinial infection which they produce on Joanette Strain at a relatively low temperature. The following grouping of certain physiologic forms is suggested for the reasons given.

Group I. Forms 1, 2 and 5. These three physiologic forms only differ in the types of infection which they produce on Joanette Strain. When this host is kept at a relatively high temperature, they are indistinguishable. There is extremely little difference between forms 1 and 5 at all temperatures.

Group II. Forms 3 and 7. These two forms also differ only in the types of uredinial infection which they produce on Joanette Strain. At relatively high temperatures they are indistinguishable.

Group III. Forms 4 and 6. For the same reasons as given for grouping forms 3 and 7. Forms 8 and 9 can be identified, as such, under ordinary environmental conditions occurring in the greenhouses.

How temperature brings about the changes in the uredinial development of forms 1, 3, 4 and 5 on the host Joanette Strain is obscure. If the effect of temperature is exerted directly on these physiologic forms, it might be supposed that their uredinial development on the other hosts would also be affected. This is not the case. If the effect of the temperature is exerted directly upon the host, Joanette Strain, this effect only occurs when this host is infected by forms 1, 3, 4 and 5. Only one effect of temperature was observed to be exerted equally on all physiologic forms growing on the four hosts, namely, that the incubation period of all forms was greatly extended at relatively low temperatures.

Johnson (*24*) concluded from the results of a study of the effect of temperature on the uredinial development of certain physiologic forms of *P. graminis tritici* that "the effect of temperature is registered on the host-parasite complex." Until more is known about the whole problem of rust resistance, this appears more likely to be the case than that the effect is directly on the host, or parasite. Harrington (*16*) suggests a "curtailment of action of the susceptibility factors", as a genetic hypothesis to explain the action of temperature in inducing rust resistance at a low temperature. This hypothesis is based on the assumption that the effect of temperature is on the host only.

Effect of Temperature on Telial Development

Review of Literature on Teliospore Formation

The formation of teliospores by the rust fungi has engaged the attention of numerous investigators for many years. Three different factors have been considered by them to be responsible for telial development. These are:

(1) Condition, or stage of development, of the host; (2) Constitution, or age, of the rust mycelium; (3) Environmental conditions.

One of the earliest theories to account for teliospore formation in the rusts in general was advanced by Magnus (*28*) in 1891. He considered that the production of teliospores was dependent on the condition of the host plant, particularly those parts bearing the parasite. Exhaustion, or previous drying of the host, was regarded as favouring, or even inducing, teliospore formation on the infected plants. Morgenthaler (*31*), working with *Uromyces Veratri* (D.C.) Wint., also considered that the condition of the host was the most important factor in inducing the formation of teliospores, but that the environment was a modifying agent. Klebahn (*25*) was of the opinion that the varying condition of the leaves plays a role in teliospore development. From a study of a number of cereal rusts, Gassner (*11*) concluded that the stage of development of the host governs the formation of teliospores and that climatic conditions, by their effect on the development of the host, can only indirectly, be a factor. The fact that *Puccinia coronata* Corda. developed teliospores on seedling leaves of some varieties of oats was regarded by Parker (*33*) as indicating resistance. Eremeyeva and Karakulin (*4*), from observations on sunflower rust, concluded that the formation of teliospores depended on the physiological condition of the host and not on its age.

In 1910, Jaczewski (*23*) suggested that the formation of teliospores in *Puccinia graminis* Pers. was probably dependent on the age of the mycelium, since climatic conditions apparently played no role. Raines (*38*), in 1922, expressed the opinion that teliospore formation in *Puccinia coronifera* Kleb. indicated the protoplasmic constitution of the fungus mycelium as a possible factor. This view has received support from investigations made more recently. Bailey (*1*), in 1925, found that forms 3 and 4 of *P. graminis avenae* formed teliospores much more rapidly than forms 1, 2 and 5. As forms 3 and 4 are much more virulent than the latter, a correlation between rapidity of teliospore formation and virulence was suggested. Parson (*34*), working with *P. coronata avenae*, and Hey (*19*), with *Puccinia simplex* Erikss. and Henn., observed striking differences also in the rapidity of telial development by various physiologic forms.

A number of investigators have regarded environmental factors as being of importance in the formation of teliospores by various rust fungi. Hennings (*18*), in 1901, was of the opinion that climatic conditions as well as the physical condition of the host might be the cause of teliospore formation. A few years later, Smith (*41*) observed that teliospore formation in *Puccinia asparagi* D.C. was rapidly brought about by high soil moistures, and appeared to be also favoured by dry winds and cool nights. In 1907, Ivanoff (*22*) determined by experiments that low temperatures were more favourable for the telial development of *Puccinia pimpinellae* (Strs.) Link., *Puccinia Galii* Schw., *Puccinia violae* (Schum.) D.C., and *Puccinia Celakowskyana* Bub. From a study of the telial development of several rust fungi, Waters (*55*) concluded that such factors as light, temperature and moisture may so influence the metabolism of the host that the fungus reacts by changing from the uredinial to the telial stage. That is, environmental factors are of importance, but are indirect in their action. Johnson (*24*), working with physiologic forms of *P. graminis tritici*, found that relatively high temperatures favoured rapid

teliospore formation, but that there were inherent differences also between forms in respect to their telial development. He observed also that most rapid telial development occurred at the nodes of the plants. In other words, environmental factors, constitution of the fungus mycelium and specific host tissues had some effect on teliospore formation. Melander (*30*) noted that the production of telia by *P. graminis* on wheat, oats and rye was stimulated at a low temperature (0 to 1°C.).

SCOPE OF STUDIES ON THE EFFECT OF TEMPERATURE ON TELIAL DEVELOPMENT

The effect of temperature on the telial development of the physiologic forms of *P. graminis avenae* was determined by inoculating certain hosts in the seedling and mature stages and then keeping them at different temperatures until the formation of teliospores was completed. With few exceptions, the various experiments were carried on at constant temperatures. As the variety Victory is susceptible to all the forms, it was employed most frequently in this part of the investigation, although in certain experiments, White Russian was also used.

In the experiments in which seedlings were inoculated, the number of seedlings bearing teliospores was recorded each day, from the end of the incubation period of the uredinia until telia were present on all the infected plants, or until further telial development was prevented by the death of the plants. From the data obtained, both the rate and extent of telial development of the various forms at the same, or different, temperatures could be compared. The rate was determined by calculating the mean of the number of days required for a physiologic form to attain complete telial development after the end of the incubation period, that is, after the first appearance of uredinia. Complete telial development of a form was considered to have been reached when telia were formed on all infected seedlings, or when further formation of teliospores was prevented by the death of the seedlings. The extent of telial development of the various physiologic forms at the same, or different, temperatures could be determined by calculating the percentage of infected seedlings on which telia were formed. A statistical analysis of the data obtained was carried out to determine the significance of the differences observed in both the rate and extent of telial development in the various physiologic forms kept at different temperatures.

When the hosts were inoculated in the mature stage, observations on teliospore formation were made each day from the end of the incubation period until teliospores were present in all uredinial pustules. The observations recorded on the rate of formation of teliospores in the various forms at different temperatures included the following data:

1. The number of days from inoculation to the formation of the first teliospores.
2. The number of days from inoculation until complete telial development had taken place.
3. The number of days from the formation of the first teliospores until until complete telial development took place.
4. The number of days from the end of the incubation period until the first teliospores were formed.
5. The number of days from the end of the incubation period until the formation of teliospores was completed.

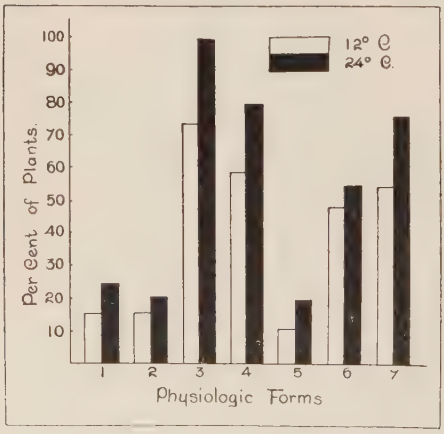
THE FORMATION OF TELIOSPORES ON VICTORY IN THE SEEDLING STAGE BY SEVEN PHYSIOLOGIC FORMS AT LOW AND HIGH TEMPERATURES (WINNIPEG)

In this experiment observations were made on the formation of teliospores in forms 1, 2, 3, 4, 5, 6 and 7 on Victory in the seedling stage at a low (12°C.) and a high temperature (24°C.). The procedure followed during each of three similar trials was to inoculate seven sets of approximately 100 seedlings of Victory with urediniospores, a different form being used for each set. Half of the seedlings of each set were later placed in a greenhouse section maintained at the low temperature and the other half of each set in a section held at the high temperature, until the formation of teliospores was completed.

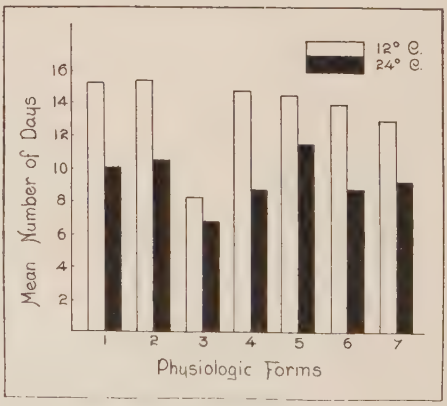
In making the statistical analysis of the results obtained at the two temperatures, the total number of seedlings under observation during the three trials were employed. The significance of the difference between the telial development of each physiologic form at the two temperatures was determined by calculating the value of χ^2, according to the method of Fisher (7). The values of the 5% point were also obtained by referring to the Tables of Fisher (7).

The method of analyzing the data concerning the telial development of each physiologic form on seedlings kept at the low and high temperatures is shown in Tables 15 and 16. The significance of the difference between the extent of the telial development in form 4 at temperatures of 12° and 24°C. was determined as shown in Table 15. In Table 16 is shown the analysis of the data concerning the rate of telial development in form 4 at the two temperatures. Data concerning the extent and rate of telial development of the other physiologic forms at the low and high temperatures were analyzed in the same manner.

The results of this experiment are presented in Table 14, and are illustrated graphically in Text Figures 5 and 6. The extent of the telial development of all physiologic forms was greater at the high (24°C.) than at the low temperature (12°C.) (Text Figure 5). With certain physiologic forms, however, the



Text Figure 5. The percentage of Victory seedlings bearing telia when infected by seven physiologic forms and kept at low and high temperatures.



Text Figure 6. The mean number of days taken by seven physiologic forms to attain complete telial development on seedlings of Victory kept at low and high temperatures.

differences in the extent of their telial development at the two temperatures were not significant, as indicated by the value of χ^2 (Table 14). Differences are considered significant when the value of χ^2 is equal to, or greater than, the 5% point.

The rate of telial development of all forms was faster at the high than at the low temperature. In all cases the differences may be considered significant (Table 14). The differences in the rate of telial development of all forms at the two temperatures are shown by means of a graph in Text Figure 6.

TABLE 14.—A STATISTICAL ANALYSIS OF THE EXTENT AND RATE OF TELIOSPORE FORMATION IN SEVEN PHYSIOLOGIC FORMS ON VICTORY IN THE SEEDLING STAGE WHEN KEPT AT LOW AND HIGH TEMPERATURES.

Forms	Temperatures	Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Mean No. of days taken to form telia	χ^2	5 per cent point
1	12°C.	15.8	2.9	3.8	15.4	22.2	7.8
	24°C.	23.9			10.1		
2	12°C.	16.3	.7	3.8	15.5	15.4	7.8
	24°C.	20.1			10.5		
3	12°C.	72.8	43.9	3.8	8.3	26.3	9.5
	24°C.	98.7			6.8		
4	12°C.	57.6	17.4	3.8	14.8	51.2	7.8
	24°C.	79.0			8.7		
5	12°C.	11.2	4.0	3.8	14.5	8.9	6.0
	24°C.	19.6			11.5		
6	12°C.	47.0	4.7	3.8	14.0	63.4	7.8
	24°C.	54.3			8.7		
7	12°C.	53.9	14.9	3.8	13.0	68.8	9.5
	24°C.	75.2			9.3		

The influence of temperature on the formation of teliospores by the various physiologic forms appeared to be as follows. A high temperature was conducive to a rapid development of teliospores, while a low temperature retarded their formation. Teliospores were formed also on a larger percentage of infected seedlings at the high (24°C.) than at the low temperature (12°C.).

Differences in the telial development of the various forms were evident. Forms 1, 2 and 5 formed telia on a smaller percentage of the infected seedlings, and did so more slowly, than forms 3, 4, 6 and 7. Form 3 developed telia on a greater percentage of infected plants, and formed them more rapidly at both temperatures, than any of the other physiologic forms.

TABLE 15.—DISTRIBUTION OF VICTORY SEEDLINGS ON WHICH TELIOSPORES FORMED, OR FAILED TO FORM, AT TWO TEMPERATURES WHEN INFECTED BY FORM 4.

	Number of seedlings		
	Formed	Failed	Totals
12°C.	87	64	151
24°C.	139	37	176
Totals	226	101	327

$\chi^2 = 17.4$ 5 per cent point = 3.8

TABLE 16.—DISTRIBUTION OF VICTORY SEEDLINGS AT TWO TEMPERATURES, ON WHICH TELIOSPORES WERE FORMED BY FORM 4 DURING FOUR CONSECUTIVE FIVE-DAY PERIODS FROM THE END OF THE INCUBATION PERIOD.

	Number of seedlings bearing telia during each five-day period				
	1	2	3	4	Totals
12°C.	1	27	38	21	87
24°C.	69	36	32	2	139
Totals	70	63	70	23	226

$\chi^2 = 51.2$ 5 per cent point = 7.8

THE FORMATION OF TELIOSPORES ON WHITE RUSSIAN IN THE SEEDLING STAGE BY EIGHT PHYSIOLOGIC FORMS AT LOW AND HIGH TEMPERATURES (WINNIPEG)

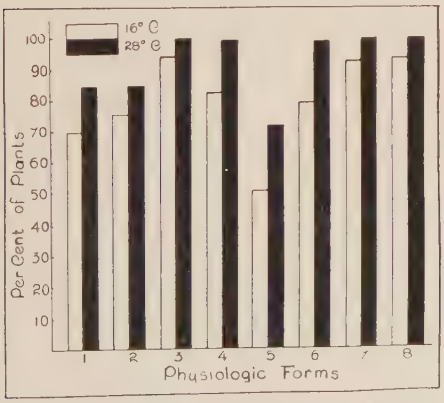
The effect of temperature on the formation of teliospores of eight physiologic forms on White Russian in the seedling stage was determined in the following experiment. In each of three trials approximately 800 seedlings of this host were inoculated with urediniospores, a different physiologic form being used to inoculate each 100 seedlings.

After inoculation, one-half the number of the seedlings inoculated with each form was kept in a section of a greenhouse maintained at 16°C., and the other half was placed in a section kept at 28°C. Observations on telial development were recorded in the usual manner. The object of this experiment was to determine whether the telial development of the various forms on this host would be more extensive and more rapidly initiated at the high temperature than at the low, as was the case when Victory was used as the host.

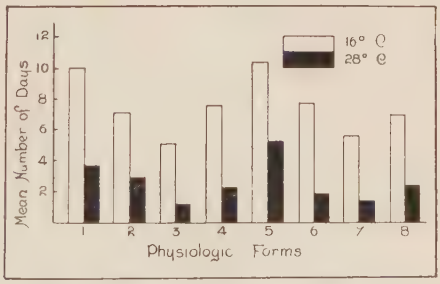
The results of this experiment, analyzed statistically, are presented in Table 17. Again, teliospore formation by all forms was more extensive at the high (28°C.) than at the low temperature (16°C.). Teliospores were formed on a greater percentage of the seedlings infected by all forms at the high temperature, as is shown graphically in Text Figure 7. There was also a shorter period of time taken for the formation of the teliospores at the high temperature, as shown by means of the graph in Text Figure 8. The statistical analysis of the results obtained at the two temperatures show that the differences between the telial development which occurred at the low (16°C.) and high temperature (28°C.) may be considered significant (Table 17). In all cases the value of χ^2 is greater than that of the 5% point.

TABLE 17.—A STATISTICAL ANALYSIS OF THE EXTENT AND RATE OF TELIOSPORE FORMATION IN EIGHT PHYSIOLOGIC FORMS ON WHITE RUSSIAN IN THE SEEDLING STAGE WHEN KEPT AT LOW AND HIGH TEMPERATURES.

Forms	Temperatures	Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Mean No. of days taken to form telia	χ^2	5 per cent point
1	16°C.	69.7	15.2	3.8	10.0	218.0	7.8
	28°C.	84.8			3.7		
2	16°C.	75.8	5.2	3.8	7.0	243.9	7.8
	28°C.	84.7			2.8		
3	16°C.	95.0	10.9	3.8	5.1	147.5	6.0
	28°C.	100.0			1.2		
4	16°C.	82.5	37.9	3.8	7.6	236.3	6.0
	28°C.	99.1			2.3		
5	16°C.	50.3	20.7	3.8	10.5	89.1	7.8
	28°C.	72.6			5.3		
6	16°C.	78.4	42.4	3.8	7.8	296.9	6.0
	28°C.	98.6			1.9		
7	16°C.	92.3	16.8	3.8	5.6	190.9	6.0
	28°C.	100.0			1.4		
8	16°C.	93.6	12.4	3.8	6.9	202.8	6.0
	28°C.	100.0			2.4		



Text Figure 7. The percentage of White Russian seedlings bearing telia when infected by eight physiologic forms and kept at low and high temperatures.



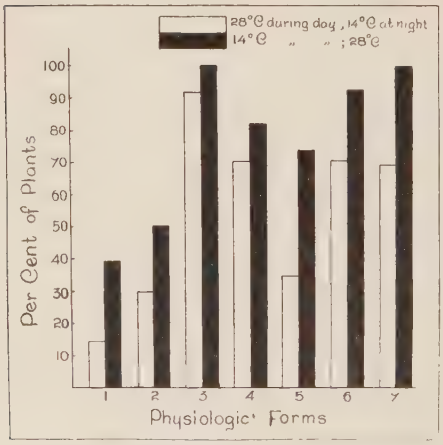
Text Figure 8. The mean number of days taken by eight physiologic forms to attain complete telial development on seedlings of White Russian kept at low and high temperatures.

Although forms 1, 2 and 5 developed teliospores on a greater percentage of the White Russian seedlings than when Victory was employed as a host, they formed teliospores less extensively than the other physiologic forms.

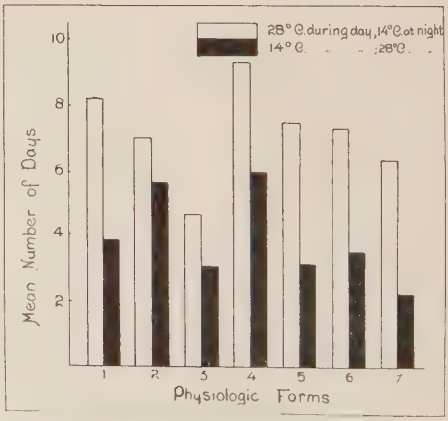
THE FORMATION OF TELIOSPORES BY SEVEN PHYSIOLOGIC FORMS ON VICTORY IN THE SEEDLING STAGE WHEN KEPT DURING THE DAY AND NIGHT AT DIFFERENT TEMPERATURES (WINNIPEG)

When teliospores are formed during the autumn under natural conditions the temperature is variable. During the day it is usually much higher than at night. In addition to the higher temperature occurring during the day, sunlight is present, while at night there is a combination of low temperature and darkness. In this experiment the teliospore formation of forms 1, 2, 3, 4, 5, 6 and 7, was observed on Victory in the seedling stage under environmental conditions approximating those occurring in nature during the autumn. Two sections of a greenhouse, one maintained at a high (28°C.) and the other at a low temperature (14°C.) were employed. In each of the three similar trials approximately 700 seedlings of Victory were inoculated with urediniospores, a different physiologic form being used to inoculate each 100 seedlings. After inoculation, half of the seedlings inoculated with each physiologic form were kept during the day at 28°C. and during the night at 14°C.; the other half were kept during the day at 14°C. and during the night at 28°C. Observations on the teliospore formation of the various physiologic forms were made in the usual manner. The incubation period was ten days under both sets of environmental conditions.

The results obtained in this experiment, analyzed statistically, are presented in Table 18. All physiologic forms formed teliospores on a greater percentage of infected seedlings when kept during the day at 14°C. and at a temperature of 28°C. at night than when kept during the day at 28°C. and at a temperature of 14°C. at night. This difference between the seven physiologic forms in the extent of their telial development under the different



Text Figure 9. The percentage of Victory seedlings bearing telia when infected by seven physiologic forms and kept under different environmental conditions.



Text Figure 10. The mean number of days taken by seven physiologic forms to attain complete telial development on seedlings of Victory kept under different environmental conditions.

environmental conditions is illustrated graphically in Text Figure 9. The different forms also attained complete telial development more rapidly on the seedlings when kept during the day at 14°C. and at a temperature of 28°C. at night, than when kept at 28°C. during the day and at a temperature of 14°C. at night. A comparison of the rate of telial development of the seven physiologic forms is made by means of a graph in Text Figure 10. It would appear from these results that a low temperature combined with light and a high temperature along with darkness are more conducive to telial development of these physiologic forms at least than a high temperature with light and a low temperature with darkness.

TABLE 18.—A STATISTICAL ANALYSIS OF THE EXTENT AND RATE OF TELIOSPORE FORMATION IN SEVEN PHYSIOLOGIC FORMS ON VICTORY IN THE SEEDLING STAGE WHEN KEPT UNDER DIFFERENT ENVIRONMENTAL CONDITIONS.

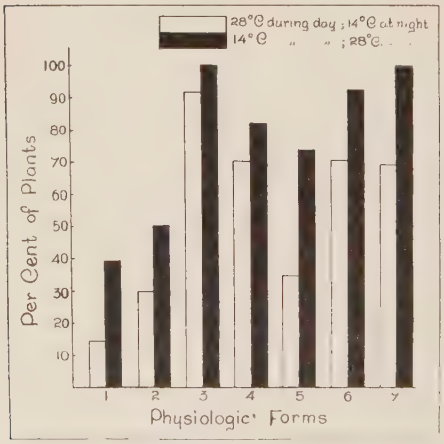
Forms	Environmental conditions	Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Mean No. of days taken to form telia	χ^2	5 per cent point
1	28°C. during day; 14°C. at night	14.0	24.6	3.8	8.2	15.8	6.0
	14°C. during day; 28°C. at night	39.3			3.8		
2	28°C. during day; 14°C. at night	29.6	24.3	3.8	7.0	7.0	7.8
	14°C. during day; 28°C. at night	51.1			5.6		
3	28°C. during day; 14°C. at night	92.8	12.1	3.8	4.6	17.4	6.0
	14°C. during day; 28°C. at night	100.0			3.1		
4	28°C. during day; 14°C. at night	70.5	6.6	3.8	9.3	47.4	7.8
	14°C. during day; 28°C. at night	82.6			5.9		
5	28°C. during day; 14°C. at night	34.2	54.8	3.8	7.4	42.5	7.8
	14°C. during day; 28°C. at night	74.8			3.2		
6	28°C. during day; 14°C. at night	71.8	22.7	3.8	7.3	108.5	7.8
	14°C. during day; 28°C. at night	92.6			3.5		
7	28°C. during day 14°C. at night	69.9	60.8	3.8	6.2	86.5	7.8
	14°C. during day; 28°C. at night	100.0			2.2		

Although forms 1, 2 and 5 developed teliospores on a greater percentage of the White Russian seedlings than when Victory was employed as a host, they formed teliospores less extensively than the other physiologic forms.

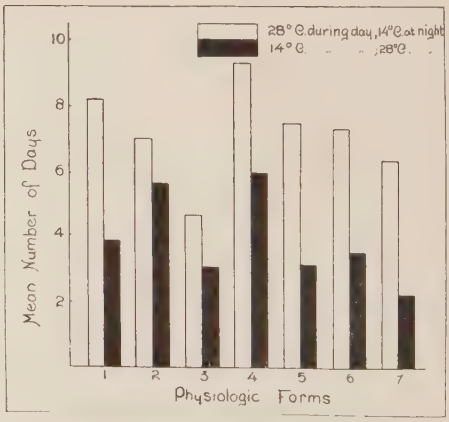
THE FORMATION OF TELIOSPORES BY SEVEN PHYSIOLOGIC FORMS ON VICTORY IN THE SEEDLING STAGE WHEN KEPT DURING THE DAY AND NIGHT AT DIFFERENT TEMPERATURES (WINNIPEG)

When teliospores are formed during the autumn under natural conditions the temperature is variable. During the day it is usually much higher than at night. In addition to the higher temperature occurring during the day, sunlight is present, while at night there is a combination of low temperature and darkness. In this experiment the teliospore formation of forms 1, 2, 3, 4, 5, 6 and 7, was observed on Victory in the seedling stage under environmental conditions approximating those occurring in nature during the autumn. Two sections of a greenhouse, one maintained at a high (28°C.) and the other at a low temperature (14°C.) were employed. In each of the three similar trials approximately 700 seedlings of Victory were inoculated with uredinio-spores, a different physiologic form being used to inoculate each 100 seedlings. After inoculation, half of the seedlings inoculated with each physiologic form were kept during the day at 28°C. and during the night at 14°C.; the other half were kept during the day at 14°C. and during the night at 28°C. Observations on the teliospore formation of the various physiologic forms were made in the usual manner. The incubation period was ten days under both sets of environmental conditions.

The results obtained in this experiment, analyzed statistically, are presented in Table 18. All physiologic forms formed teliospores on a greater percentage of infected seedlings when kept during the day at 14°C. and at a temperature of 28°C. at night than when kept during the day at 28°C. and at a temperature of 14°C. at night. This difference between the seven physiologic forms in the extent of their telial development under the different



Text Figure 9. The percentage of Victory seedlings bearing telia when infected by seven physiologic forms and kept under different environmental conditions.

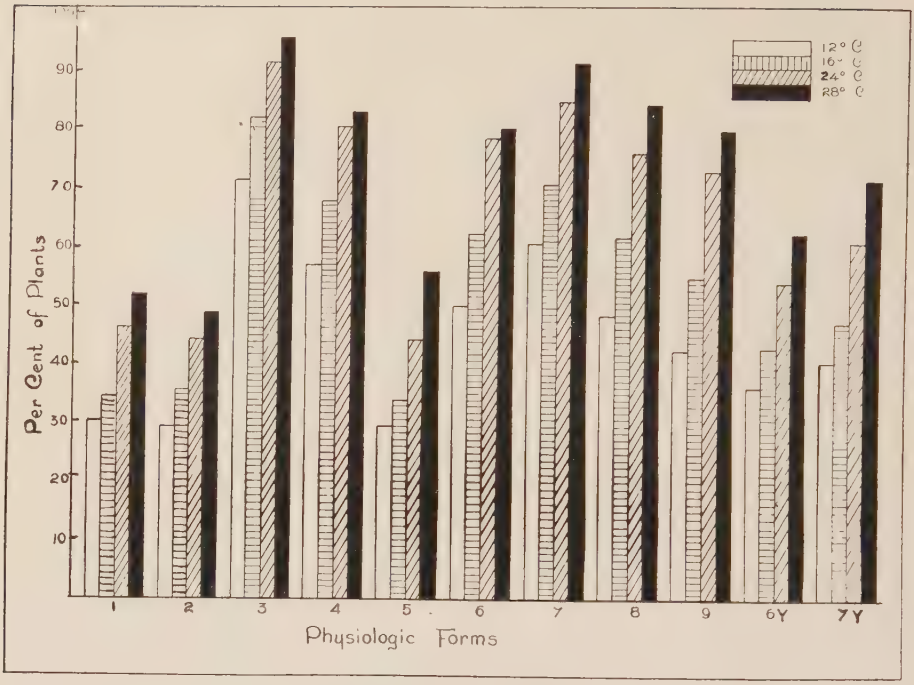


Text Figure 10. The mean number of days taken by seven physiologic forms to attain complete telial development on seedlings of Victory kept under different en-environmental conditions.

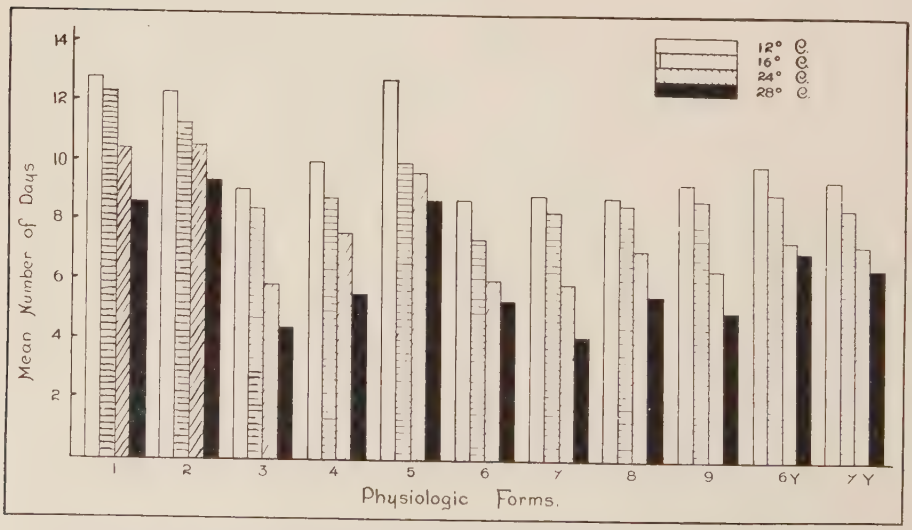
environmental conditions is illustrated graphically in Text Figure 9. The different forms also attained complete telial development more rapidly on the seedlings when kept during the day at 14°C. and at a temperature of 28°C. at night, than when kept at 28°C. during the day and at a temperature of 14°C. at night. A comparison of the rate of telial development of the seven physiologic forms is made by means of a graph in Text Figure 10. It would appear from these results that a low temperature combined with light and a high temperature along with darkness are more conducive to telial development of these physiologic forms at least than a high temperature with light and a low temperature with darkness.

TABLE 18.—A STATISTICAL ANALYSIS OF THE EXTENT AND RATE OF TELIOSPORE FORMATION IN SEVEN PHYSIOLOGIC FORMS ON VICTORY IN THE SEEDLING STAGE WHEN KEPT UNDER DIFFERENT ENVIRONMENTAL CONDITIONS.

Forms	Environmental conditions	Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Mean No. of days taken to form telia	χ^2	5 per cent point
1	28°C. during day; 14°C. at night	14.0	24.6	3.8	8.2	15.8	6.0
	14°C. during day; 28°C. at night	39.3			3.8		
2	28°C. during day; 14°C. at night	29.6	24.3	3.8	7.0	7.0	7.8
	14°C. during day; 28°C. at night	51.1			5.6		
3	28°C. during day; 14°C. at night	92.8	12.1	3.8	4.6	17.4	6.0
	14°C. during day; 28°C. at night	100.0			3.1		
4	28°C. during day; 14°C. at night	70.5	6.6	3.8	9.3	47.4	7.8
	14°C. during day; 28°C. at night	82.6			5.9		
5	28°C. during day; 14°C. at night	34.2	54.8	3.8	7.4	42.5	7.8
	14°C. during day; 28°C. at night	74.8			3.2		
6	28°C. during day; 14°C. at night	71.8	22.7	3.8	7.3	108.5	7.8
	14°C. during day; 28°C. at night	92.6			3.5		
7	28°C. during day 14°C. at night	69.9	60.8	3.8	6.2	86.5	7.8
	14°C. during day; 28°C. at night	100.0			2.2		



Text Figure 11. The percentage of Victory seedlings bearing telia when infected by nine physiologic forms and kept at four different temperatures.



Text Figure 12. The mean number of days taken by nine physiologic forms to attain complete telial development on seedlings of Victory at four different temperatures.

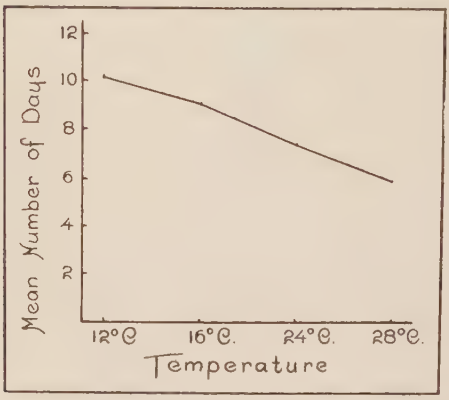
TABLE 20.—DATA CONCERNING THE EXTENT AND RATE OF TELIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS WHEN KEPT AT LOW (12° AND 16°C.) AND HIGH TEMPERATURES (24° AND 28°C.).

Forms	Temperatures °C.	Extent of Telial Development: Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Rate of Telial Development: Mean number of days taken to form telia	χ^2	5 per cent point
1	12°, 16°	32.7	16.8	3.8	12.4	36.7	6.0
	24°, 28°	49.1			9.5		
2	12°, 16°	32.5	16.0	3.8	11.8	16.0	6.0
	24°, 28°	46.3			9.9		
3	12°, 16°	75.6	36.2	3.8	8.8	81.4	6.0
	24°, 28°	93.4			5.2		
4	12°, 16°	62.3	24.7	3.8	9.4	66.1	6.0
	24°, 28°	81.6			6.6		
5	12°, 16°	31.4	18.6	3.8	11.3	27.0	6.0
	24°, 28°	48.8			9.3		
6	12°, 16°	55.9	23.9	3.8	8.1	55.8	6.0
	24°, 28°	78.8			5.7		
7	12°, 16°	65.4	40.9	3.8	8.7	92.7	6.0
	24°, 28°	87.6			5.1		
8	12°, 16°	55.1	41.5	3.8	8.8	61.5	6.0
	24°, 28°	79.8			6.3		
9	12°, 16°	47.9	48.5	3.8	9.1	73.7	6.0
	24°, 28°	75.9			5.8		
6Y	12°, 16°	39.3	20.7	3.8	11.2	21.6	6.0
	24°, 28°	57.9			6.3		
7Y	12°, 16°	43.4	30.9	3.8	9.1	33.9	6.0
	24°, 28°	66.0			7.0		

The relation of temperature to the rate of teliospore formation in stem-rust of oats (*P. graminis avenae*) on seedlings of Victory is shown by means of a graph in Text Figure 13. The rate of formation at each of the four different temperatures is expressed by the mean number of days taken by all the physiologic forms to attain complete telial development. It would appear evident that, within the temperature range of this experiment, the rate of formation of teliospores in this rust is increased by a rise in temperature.

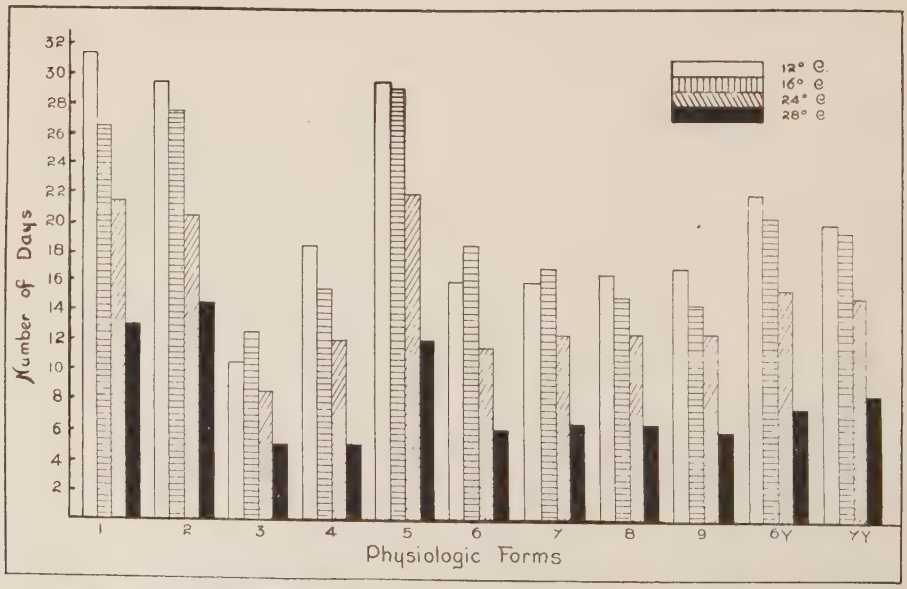
THE FORMATION OF TELIOSPORES BY NINE PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE AT FOUR TEMPERATURES (MADISON)

In this experiment, the formation of teliospores in nine physiologic forms of *P. graminis avenae* was investigated on Victory in the mature stage. Forms 6Y and 7Y, yellow in colour, were also included. During each of two similar trials, a set of four pots of Victory in the mature stage was inoculated with form 1, a second set with form 2, and so on for the other forms. Each pot contained five plants. After the pots were removed from the incubation chambers, one pot of each set was placed in each of the four controlled chambers maintained at temperatures of 12°, 16°, 24° and 28°C. Observations were made daily on the telial development of the different physiologic forms. The incubation period of all physiologic forms on the mature plants was the same as that which occurred when seedlings were inoculated.



Text Figure 13. A graph showing the relation of temperature to the rate of telial development by *P. graminis avenae* on seedlings of Victory: the mean number of days taken by the nine physiologic forms to attain complete telial development on seedlings of Victory kept at four different temperatures.

Data concerning the formation of teliospores by the nine physiologic forms on Victory in the mature stage when kept at the four different temperatures are presented in Tables 21 to 24. The number of days taken by the different forms to attain complete telial development from the end of the



Text Figure 14. A comparison of the rate of teliospore formation by nine physiologic forms on Victory in the mature stage kept at four different temperatures.

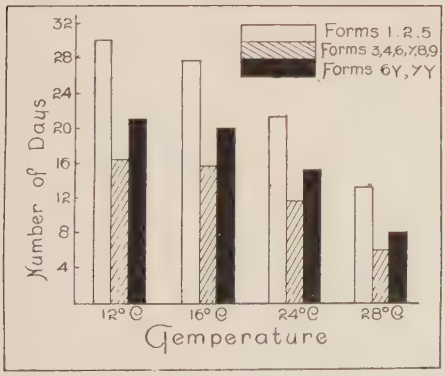
incubation period is employed in Text Figure 14 as the index for the comparison of their rate of telial development at the four different temperatures. It will be evident from Text Figure 14 that all the physiologic forms produced teliospores most rapidly at a temperature of 28°C. At successively lower temperatures their rate of telial development, with few exceptions, was more and more decreased. These results are in close agreement with those obtained when seedlings were inoculated with the same physiologic forms and kept at the same temperatures. It would appear that high temperatures are most favourable for the rapid telial development of all the physiologic forms on both seedlings and mature plants.

Forms 1, 2 and 5 again formed teliospores more slowly at each of the four different temperatures than the other physiologic forms. This was the case when the rate of their telial development was determined on Victory in the seedling stage. Forms 6Y and 7Y formed teliospores more rapidly than forms 1, 2 and 5, but more slowly than forms 3, 4, 6, 7, 8 and 9. Data concerning the rate of telial development of these three groups of physiologic forms at the four temperatures, are presented in Table 25. The mean number of days is stated in each case. A comparison of the rate of formation of teliospores by the three groups of physiologic forms kept at the four different temperatures is made graphically in Text Figure 15. The number of days taken by each group of physiologic forms to attain complete telial development from the end of the incubation period was employed as the index of the rate in each case.

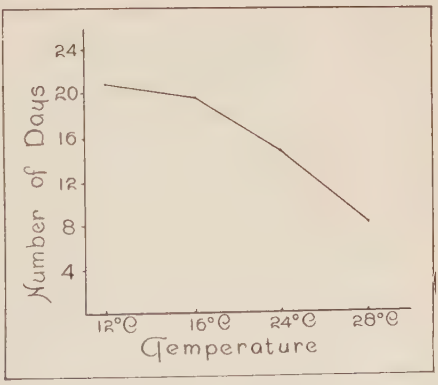
The relation of temperature to the rate of telial development of *P. graminis avenae* on Victory in the mature stage is shown by means of a graph in Text Figure 16. The mean number of days taken by all the physiologic forms to attain complete telial development from the end of the incubation period was employed as the index of the rate of telial development.

THE FORMATION OF TELIOSPORES BY EIGHT PHYSIOLOGIC FORMS ON VICTORY AND WHITE RUSSIAN IN THE MATURE STAGE KEPT UNDER DIFFERENT ENVIRONMENTAL CONDITIONS (WINNIPEG)

The rate of formation of teliospores by eight physiologic forms on the hosts Victory and White Russian in the mature stage was determined under



Text Figure 15. A comparison of the rate of teliospore formation by three groups of physiologic forms on Victory in the mature stage kept at four different temperatures.



Text Figure 16. A graph showing the relation of temperature to the rate of telial development by *P. graminis avenae* on Victory in the mature stage.

different environmental conditions. In this experiment 48 pots of each host were inoculated with urediniospores, six pots of Victory and six of White Russian being inoculated with form 1, the same number of each host with form 2, and similarly for the other six forms. After inoculation, the various pots of hosts were apportioned as follows. Two out of the six pots of each host inoculated with form 1 were placed in a cold section of the greenhouse and two in a warm section. A similar distribution was made for each of the other forms. Accurate control of the temperature could not be obtained in either of the two sections, as this experiment was carried on during May and June, when the sun's rays were strong. The mean temperatures, however, of the two sections were quite different, being 16°C. in the cold section during this experiment and 26°C. in the warm section. The two remaining pots were placed outside the greenhouse where wide variations occurred in the environment.

TABLE 21.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE WHEN KEPT AT A TEMPERATURE OF 12°C.

Forms	Number of days				
	From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	27	47.5	20.5	11	31.5
2	25.5	45.5	20	9.5	29.5
3	16.5	26.5	10	.5	10.5
4	19	35	16	3	19
5	26.5	45.5	19	10.5	29.5
6	20	35.5	15.5	4	16
7	20	32	12	4	16
8	20	32.5	12.5	4	16.5
9	20	33	13	4	17
6(Y)	23	38	15	7	22
7(Y)	23	36	13	7	20

TABLE 22.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE WHEN KEPT AT A TEMPERATURE OF 16°C.

Forms	Number of days				
	From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	23.5	38.5	15	11.5	26.5
2	24.5	39.5	15	12.5	27.5
3	17.5	24.5	7	5.5	12.5
4	18.5	27.5	9	6.5	15.5
5	24.5	41	16.5	12.5	29
6	20	30.5	10.5	8	18.5
7	18	29	11	6	17
8	18	27	9	6	15
9	17.5	26.5	9	5.5	14.5
6(Y)	21.5	32.5	11	9.5	20.5
7(Y)	20	31.5	11.5	8	19.5

TABLE 23.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE WHEN KEPT AT A TEMPERATURE OF 24°C.

Forms	Number of days				
	From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	19	29.5	10.5	11	21.5
2	18	28.5	10.5	10	20.5
3	10	16.5	6.5	2	8.5
4	13	20	7	5	12
5	18	30	12	10	22
6	13.5	19.5	6	5.5	11.5
7	12.5	20.5	8	4.5	12.5
8	11.5	20.5	9	3.5	12.5
9	11	20.5	9.5	3	12.5
6(Y)	14.5	23	8.5	6.5	15
7(Y)	14.5	23	8.5	6.5	15

TABLE 24.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF NINE PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE WHEN KEPT AT A TEMPERATURE OF 28°C.

Forms	Number of days				
	From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	12.5	22	9.5	3.5	13
2	12	23.5	11.5	3	14.5
3	9	14	5	0	5
4	9	14	5	0	5
5	11	21	10	2	12
6	10	15	5	1	6
7	10	15.5	5.5	1	6.5
8	10	15.5	5.5	1	6.5
9	9.5	15	5.5	.5	6
6(Y)	11	16.5	5.5	2	7.5
7(Y)	10.5	17.5	7	1.5	8.5

In the cold section and outside the greenhouse, the incubation period of the various physiologic forms was twelve days, while in the warm section it was seven days.

Data concerning the rate of telial development of the various physiologic forms on the two hosts kept under the different environmental conditions are presented in Tables 26 to 28. Teliospore formation was more rapid on both hosts kept in the warm section (26°C.) of the greenhouse than when kept in the cold section (16°C.) or outside the greenhouse. Differences between the rates of teliospore formation of the different physiologic forms on Victory and White Russian kept under the same environmental conditions were not uniform. That is, one host could not be considered to have induced more rapid telial development in all the physiologic forms than the other when both were kept under the same conditions. The rate of formation of teliospores by the eight physiologic forms on the hosts Victory and White

TABLE 25.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF THREE GROUPS OF PHYSIOLOGIC FORMS ON VICTORY IN THE MATURE STAGE WHEN KEPT AT FOUR DIFFERENT TEMPERATURES.

Temperatures	Forms	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
12°C.	1, 2, 5	26.3	46.2	19.9	10.3	30.2
	3, 4, 6, 7, 8, 9	19.3	32.4	13.1	3.3	16.4
	6Y, 7Y	23	37	14	7	21
16°C.	1, 2, 5	24.2	39.7	15.5	12.2	27.7
	3, 4, 6, 7, 8, 9	18.3	27.5	9.2	6.3	15.5
	6Y, 7Y	20.8	32	11.2	8.8	20
24°C.	1, 2, 5	18.3	29.3	11	10.3	21.3
	3, 4, 6, 7, 8, 9	11.9	19.6	7.7	3.9	11.6
	6Y, 7Y	14.5	23	8.5	6.5	15
28°C.	1, 2, 5	11.7	22.2	10.5	2.7	13.2
	3, 4, 6, 7, 8, 9	9.6	14.8	5.2	.6	5.8
	6Y, 7Y	10.8	17	6.2	1.8	8

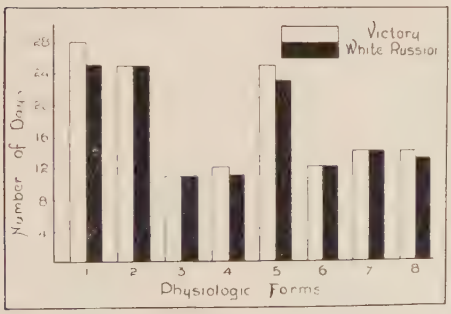
TABLE 26.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF EIGHT PHYSIOLOGIC FORMS ON VICTORY AND WHITE RUSSIAN IN THE MATURE STAGE KEPT IN A SECTION OF A GREENHOUSE AT A MEAN TEMPERATURE OF 26°C.

Forms	Hosts	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	Victory	18	35	17	11	28
	White Russian	18	32	14	11	25
2	Victory	18	32	14	11	25
	White Russian	18	32	14	11	25
3	Victory	9	18	9	2	11
	White Russian	10	18	8	3	11
4	Victory	9	19	10	2	12
	White Russian	10	18	8	3	11
5	Victory	17	32	15	10	25
	White Russian	18	30	12	11	23
6	Victory	10	19	9	3	12
	White Russian	10	19	9	3	12
7	Victory	10	21	11	3	14
	White Russian	10	21	11	3	14
8	Victory	10	21	11	3	14
	White Russian	10	20	10	3	13

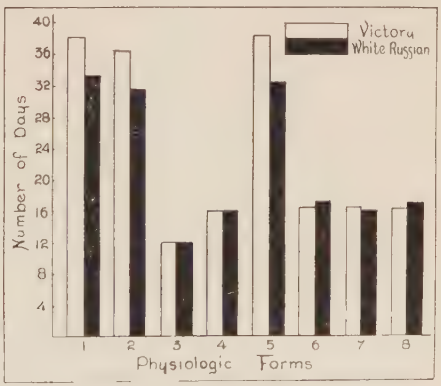
TABLE 27.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF EIGHT PHYSIOLOGIC FORMS ON VICTORY AND WHITE RUSSIAN IN THE MATURE STAGE KEPT IN A SECTION OF A GREENHOUSE AT A MEAN TEMPERATURE OF 16°C.

Forms	Hosts	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	Victory	22	50	28	10	38
	White Russian	22	45	23	10	33
2	Victory	21	48	27	9	36
	White Russian	21	43	22	9	31
3	Victory	12	24	12	0	12
	White Russian	14	24	10	2	12
4	Victory	13	28	15	1	16
	White Russian	15	28	13	3	16
5	Victory	24	50	26	12	38
	White Russian	25	44	19	13	32
6	Victory	14	28	14	2	16
	Whire Russian	14	29	15	2	17
7	Victory	14	29	15	2	17
	White Russian	14	28	14	2	16
8	Victory	14	28	14	2	16
	White Russian	15	29	14	3	17

Russian kept under the different environmental conditions is compared graphically in Text Figures 17 to 19. The number of days taken by the different physiologic forms to attain complete telial development from the end of the incubation period is the index used for the comparison of their rate of



Text Figure 17. A comparison of the rate of teliospore formation by eight physiologic forms on Victory and White Russian in the mature stage kept at a mean temperature of 26°C.

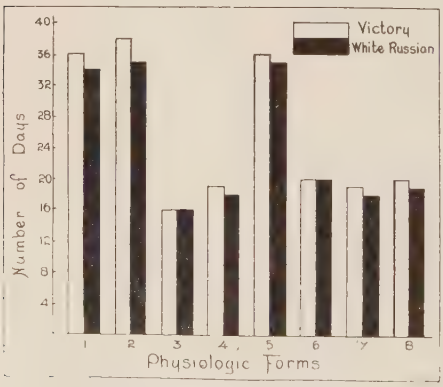


Text Figure 18. A comparison of the rate of teliospore formation by eight physiologic forms on Victory and White Russian in the mature stage kept at a mean temperature of 16°C.

TABLE 28.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF EIGHT PHYSIOLOGIC FORMS ON VICTORY AND WHITE RUSSIAN IN THE MATURE STAGE KEPT OUTSIDE THE GREENHOUSE.

Forms	Hosts	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telia to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
1	Victory	32	48	16	20	36
	White Russian	29	46	17	17	34
2	Victory	31	50	19	19	38
	White Russian	32	47	15	20	35
3	Victory	16	28	12	4	16
	White Russian	17	28	11	5	16
4	Victory	16	31	15	4	19
	White Russian	18	30	12	6	18
5	Victory	33	48	15	21	36
	White Russian	31	47	16	19	35
6	Victory	18	32	14	6	20
	White Russian	19	32	13	7	20
7	Victory	18	31	13	6	19
	White Russian	18	30	12	6	18
8	Victory	20	32	12	8	20
	White Russian	19	31	12	7	19

telial development. There was a marked difference between the rate of formation of teliospores of forms 1, 2 and 5 and that of the other physiologic forms. Under all the different environmental conditions, forms 1, 2 and 5 formed teliospores much more slowly than did forms 3, 4, 6, 7 and 8.



Text Figure 19. A comparison of the rate of teliospore formation by eight physiologic forms on Victory and White Russian in the mature stage kept outside the greenhouse.

Discussion of Results

The results obtained from the various experiments show that temperature has a marked effect on the rate of teliospore formation by the different physiologic forms of *P. graminis avenae*. These results are in accord with those obtained by Johnson (*24*) working with physiologic forms of *P. graminis tritici*. At relatively high temperatures (24° to 28°C.), teliospore formation by all physiologic forms took place much more rapidly than at relatively low temperatures (12° to 16°C.).

The stage of development of the host was not found to be an important factor in the formation of teliospores by any of the physiologic forms at either high or low temperatures; all physiologic forms developed teliospores on both

seedlings and mature plants. These results do not substantiate the conclusions of Gassner (*11*) that the development of teliospores by the cereal rusts is independent of external conditions but dependent on a certain stage of maturity of the host plant. Johnson (*24*) observed that teliospores of *P. graminis tritici* formed most rapidly at the nodes of mature plants. This was not found to be the case in *P. graminis avenae*. While teliospores generally formed first on the lower leaves it cannot be stated that any specific host tissue invariably induced the most rapid telial development of the physiologic forms of *P. graminis avenae*.

Inherent differences in the capability of certain groups of physiologic forms to form teliospores were apparent. Within the temperature range employed, forms 1, 2 and 5 developed teliospores more slowly on both seedlings and mature plants than forms 3, 4, 6, 7, 8 and 9. These results are in agreement with those obtained by Bailey (*1*), who found that forms 3 and 4 formed teliospores with greater rapidity than forms 1, 2 and 5. As forms 3 and 4 are more virulent than the latter forms, he suggested that a correlation between rapidity of teliospore formation and virulence might exist. Such a correlation is indicated by the results of the present study. Forms 3, 4, 6, 7, 8 and 9 are more virulent than forms 1, 2 and 5, and all in the former group form teliospores more rapidly than do those in the latter group.

It is of interest to note that while forms 1, 2 and 5 were the most prevalent physiologic forms occurring in Canada during the six-year period 1925-1930, forms 3, 4, 6, 7, 8 and 9 were isolated rarely (Text Figure 3). That the rarity of these virulent physiologic forms in Canada may be due to their rapid transition into the telial stage is suggested by the results of this study. Inasmuch as these virulent forms develop teliospores more rapidly than forms 1, 2 and 5, and form telia more rapidly at a high than at a low temperature, it appears probable that they may not become distributed during the summer as rapidly as forms 1, 2 and 5, owing to curtailment of urediniospore production. A further factor which may possibly limit the prevalence of these virulent physiologic forms is that the teliospores which they form during the summer, when the temperature is high, may not be germinable. In 1898, Eriksson (*6*) suggested that only the teliospores produced by certain cereal rusts during the late autumn succeed in germinating the following spring. Johnson (*24*), in 1931, found by experiments carried on in the greenhouse that the teliospores of physiologic forms of *P. graminis tritici*, when formed at high temperatures (70°-75°C.), germinated less readily than did those formed at low temperatures (55°-60°C.).

The Relation of Atmospheric Humidity to the Telial Development of Certain Physiologic Forms

Our knowledge concerning the effect of atmospheric humidity on the formation of teliospores is limited. Certain workers, however, have noted that this factor is apparently capable of influencing the rate of telial development. As early as 1904, Smith (*41*) observed that a dry atmosphere was conducive to the rapid formation of teliospores by *P. asparagi*. Waters (*55*) was able to demonstrate by experiments that the telial development of this rust was favoured by a low atmospheric humidity. That is, teliospores were formed more rapidly when the moisture content of the air sur-

rounding the host was low than when it was high. When wheat seedlings were infected with *P. graminis tritici* and grown under bell jars in the greenhouse, Johnson (*24*) observed that "all pustules on leaves covered by the bell jars contained teliospores, while no teliospores were present on the check plants which were uncovered". This was considered to be due possibly to the higher humidity of the air within the bell jars.

THE FORMATION OF TELIOSPORES BY FORMS 2 AND 3 ON VICTORY IN THE SEEDLING AND MATURE STAGES WHEN KEPT AT LOW AND HIGH ATMOSPHERIC HUMIDITIES (MADISON)

The effect of atmospheric humidity on the telial development of forms 2 and 3 on the host Victory in the seedling and mature stages was investigated in this experiment. These two physiologic forms were chosen for study because of the apparently inherent difference in their capability to form teliospores. It has been shown in previous experiments that form 2 attains complete telial development much more slowly than form 3.

Seedlings and mature plants of the host Victory were inoculated with urediniospores of each of the two physiologic forms. Thirty pots of seedlings and eight pots of this host in the mature stage were inoculated with form 2 and an equal number with form 3. The pots were kept for the usual length of time in the incubation chambers before being distributed as follows. Half the number of pots inoculated at the two stages of development with each of the two physiologic forms were placed in a chamber in the greenhouse maintained at a relative humidity of 40%, and the remaining pots were kept in another chamber at a relative humidity of 80%. In both chambers, the temperature was maintained at 24°C. Observations on the formation of teliospores were made in the usual manner. Uredinia on the seedlings and the mature plants in both chambers first appeared eight days after inoculation.

It will be evident from Table 30 that both the extent and the rate of telial development of forms 2 and 3 were affected by humidity. Both physiologic forms developed teliospores on a greater percentage of the infected seedlings when kept at a high relative humidity (80%) than at a low one (40%). Teliospores formed more rapidly also on the seedlings kept at the higher humidity. The statistical analysis of the data (Table 30) obtained in this experiment shows that, for both physiologic forms, the differences in the extent and rate of telial development which occurred at the two humidities may be considered significant. The values of χ^2 in all cases are equal to, or greater than, the 5% points.

The effect of atmospheric humidity on the telial development of forms 2 and 3 on mature plants was different from that on seedlings. On the mature plants the formation of teliospores by both physiologic forms took place with slightly greater rapidity at the lower relative humidity (40%), as is shown in Table 31. It might be pointed out here that the low humidity was unfavourable for the development of both the seedlings and mature plants, particularly for the latter, as these plants ripened prematurely under the conditions of a high temperature (24°C.) and a low humidity (40%).

While the experiment is not sufficiently extensive to warrant drawing final conclusions, the results at least indicate that a high relative humidity was conducive to teliospore formation on seedlings but not on mature plants.

With respect to the seedling plants, these results corroborate those of Johnson (*24*), and for the mature plants, they seem to confirm the findings of Smith (*41*) and Waters (*55*).

THE EFFECT OF ULTRA-VIOLET RADIATION ON THE UREDINIAL AND TELIAL DEVELOPMENT OF CERTAIN PHYSIOLOGIC FORMS

Ultra-violet radiation has been shown in the past to have a profound effect on the development of various fungi. A number of workers (*21*, *37*, *39*, *47*, *48*, *49*, *50*) have observed that it is capable of producing striking effects on the development of both the asexual and sexual stages of certain species. Fulton and Coblenz (*10*) have shown that ultra-violet rays possess definite fungicidal properties, spores being killed after a comparatively short exposure to such rays. Some spores, however, could survive longer exposures than others, and this was attributed to the protective colouration or composition of the spore-wall. Growing mycelium was stated to be more easily killed than ungerminated spores. Weston and Halnan (56) found that in many cases the mycelium was not killed but, instead, growth was inhibited for some considerable time.

Weston (*57*, *58*, *59*, *60*) has recently studied the behaviour of a number of disease organisms under different conditions of light. Urediniospores of different physiologic forms of *P. graminis tritici* and *P. graminis avenae* were found to be incapable of germination under strong sunlight. When the

TABLE 30.—THE FORMATION OF TELIOSPORES BY FORMS 2 AND 3 ON VICTORY IN THE SEEDLING STAGE AT RELATIVE HUMIDITIES OF 40 AND 80 PER CENT.

Forms	Relative humidity Per cent	Extent of telial development: Percentage of infected plants bearing telia	χ^2	5 per cent point	Rate of telial development: Number of days taken to form telia	χ_2	5 per cent point
2	40	28.0	40.4	3.8	5.1	6.0	6.0
	80	63.6			4.1		
3	40	79.6	26.0	3.8	5.9	34.5	6.0
	80	97.2			3.9		

TABLE 31.—THE FORMATION OF TELIOSPORES BY FORMS 2 AND 3 ON VICTORY IN THE MATURE STAGE AT RELATIVE HUMIDITIES OF 40 AND 80 PER CENT.

Forms	Relative humidity Per cent	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telia to to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
2	40	15	24	9	7	16
	80	16	26	10	8	18
3	40	10	17	7	2	9
	80	11	19	8	3	11

urediniospores were covered by Wratten light filters and exposed to sunlight, abundant germination took place under the green and blue filters but only occasionally did any spores germinate under the red, scarlet, orange, yellow and purple filters. The germination of the urediniospores of *P. graminis tritici* was also found to be greatly reduced when these spores were subjected to ultra-violet rays produced by a quartz mercury-vapour lamp.

The following experiments were undertaken to determine whether or not ultra-violet rays affected the uredinial or telial development of physiologic forms of *P. graminis avenae.*

MATERIALS

In the experiments at Winnipeg, the source of light was a quartz mercury-vapour lamp. This was the Home Model Alpine Sun Lamp (alternating current, 110 volts, 60 cycle), manufactured by the Hanovia Chemical and Manufacturing Company, Newark, New Jersey. In the experiments at Madison, the source of light was a Burdick Sun Lamp, manufactured by the Burdick Corporation, Milton, Wisconsin.

EXPERIMENTS AT WINNIPEG

To investigate the effect of ultra-violet light on the uredinial development of forms 1 and 2, twenty-five pots of seedlings of each of the hosts, Victory, White Russian, Richland and Joanette Strain, were inoculated with urediniospores of form 1, and the same number of pots of each host with form 2. After inoculation, the various pots of seedlings were kept for the usual period of time in the incubation chambers. As soon as the plants had dried after removal from the chambers, they were subjected to treatment. Of the pots inoculated with form 1, five of each were kept as checks, and the remaining twenty of each host were divided into four equal lots. One lot of each host was irradiated for 15 minutes, a second for 30, a third for 60 and the fourth lot for 90 minutes at a distance of 42 inches from the source of the light. The

TABLE 32.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY TWO PHYSIOLOGIC FORMS ON FOUR HOSTS WHEN IRRADIATED WITH ULTRA-VIOLET LIGHT.

Forms	Hosts	Checks	Irradiated			
			15 minutes	30 minutes	60 minutes	90 minutes
1	Victory	45/45(4)	40/40(4)–	40/40(4)	42/42(4)	41/41(4)
	White Russian	48/48(3)$\bar{c}$	41/41(3)$\bar{c}$	46/46(3)$\bar{c}$	42/42(3)$\bar{c}$	50/50(3)$\bar{c}$
	Richland	57/58(2)$\bar{\bar{c}}$	43/43(2)–	50/50(2)$\bar{c}$	43/45(2)–	53/53(2)–
	Joanette Strain	5(x)–9(1);23 / 40	2(x)–18(1)–;20 / 40	3(x)21(1)–;17 / 40	6(x) 18(1)–;24 / 50	4(x)–23(1)–;20 / 47
2	Victory	42/42(4)	46/46(4)	40/40(4)–	46/47(4)	45/45(4)
	White Russian	48/48(3)$\bar{c}$	44/44(3)$\bar{c}$	46/46(3)$\bar{c}$	52/52(3)$\bar{c}$	50/50(3)$\bar{c}$
	Richland	41/42(2)–	54/54(2)–	53/53(2)–	46/46(2)–	47/47(2)–
	Joanette Strain	46/46(4)	47/47(4)	43/44(4)	47/47(4)	49/49(4)–

TABLE 33.—DATA CONCERNING THE FORMATION OF TELIOSPORES BY FORMS 1, 2, 3 AND 4 ON VICTORY IN THE SEEDLING STAGE WHEN IRRADIATED WITH ULTRA-VIOLET LIGHT

Forms	Treatments	Percentage of infected seedlings bearing telia	χ^2	5 per cent point	Mean number of days taken to form telia	χ^2	5 per cent point
1	Check	70.9			3.4		
	15 minutes	76.6			4.0		
	30 "	76.2	2.2	9.5	3.7	7.9	9.5
	60 "	77.3			3.2		
	90 "	71.8			3.3		
	Check	70.9	.9	3.8	3.4	2.2	3.8
	All treatments	75.9			3.5		
2	Check	79.1			3.8		
	15 minutes	72.4			4.8		
	30 "	77.4	7.8	9.5	4.5	6.5	9.5
	60 "	77.3			4.1		
	90 "	75.7			4.4		
	Check	79.1	2.8	3.8	3.8	2.9	3.8
	All treatments	75.7			4.4		
3	Check	99.1			1.8		
	15 minutes	99.0			2.5		
	30 "	99.2	6.7	9.5	1.9	9.3	9.5
	60 "	95.8			1.7		
	90 "	99.1			1.7		
	Check	99.1	.5	3.8	1.8	.6	3.8
	All treatments	98.3			1.9		
4	Check	94.2			2.8		
	15 minutes	88.8			3.3		
	30 "	90.7	2.4	9.5	3.6	3.9	9.5
	60 "	91.4			3.0		
	90 "	93.0			3.3		
	Check	94.2			2.8		
	All treatments	91.0	1.1	3.8	3.3	1.5	3.8

pots inoculated with form 2 were given similar disposition. The checks as well as the treated pots were placed in the same section of the greenhouse, the mean temperature of which was 15°C. during the experiment.

The types of uredinial infection produced by forms 1 and 2 on the check and irradiated seedlings are shown in Table 32. There was no appreciable difference in the uredinial development of either of the two physiologic forms on any of the hosts, whether irradiated or not. The seedlings irradiated for 90 minutes, however, showed definite signs of injury. The injury to the seedlings made itself apparent in the dessication of the tip and margin of the leaves. Uredinia on the uninjured parts of the leaves were in no way different from those produced on uninjured seedlings. Differences in the sensitivity of the four hosts to the ultra-violet light were not observed.

In an experiment to determine whether or not ultra-violet light affected the telial development in *P. graminis avenae* 100 pots of Victory in the seedling stage were divided into four sets of 25 pots each and inoculated with uredinio-

spores of form 1, 2, 3 and 4, a different form being used for each set. This experiment was repeated. After inoculation the procedure followed was essentially the same as that stated in the previous experiment. All the pots of seedlings were kept in a section of the greenhouse, the mean temperature of which was 24°C. during the experiment. The incubation period of the different physiologic forms was seven days, regardless of the length of exposure of the plants to the ultra-violet light.

A statistical analysis of the results of this experiment is presented in Table 33. There were no significant differences between the extent or the rate of telial development which occurred on the check and on any of the treated seedlings. The values of χ^2 are larger in all cases than those of the 5% points. These results are in agreement with those of Weston (*59*), who found that ultra-violet light did not hasten the formation of teliospores in *P. coronata.*

Experiments at Madison

The effect of ultra-violet light on the uredinial development of forms 3, 4 and 5 as well as of forms 1 and 2 was investigated at Madison, but in this experiment, Joanette Strain in the seedling and mature stages alone was used as a host. One set of eight pots of seedling plants and two pots of mature plants of this host were inoculated with urediniospores of form 1; a similar set was inoculated with form 2, and so on for forms 3, 4 and 5. Following inoculation, the various pots were kept for 48 hours in the incubation chambers. On removal, they were placed in a controlled chamber maintained at a temperature of 16°C. and a relative humidity of 75%. Four pots of seedlings and one pot of mature plants from each set were irradiated for one hour each day until final records on uredinial development were taken, the lamp being placed 36 inches from the plants. The remaining pots were kept as checks.

The results of this experiment are presented in Tables 34 and 35. It will be noted that the types of uredinial infection produced by the different physiologic forms on the irradiated plants were not appreciably different from those produced on the check plants. There was also no difference between the incubation period of the forms on the irradiated and the check plants.

To ascertain what effect ultra-violet light had on the telial development of forms 2 and 3 on Victory in the mature stage, six pots of this host in the mature stage were inoculated with urediniospores of form 2, and six similar pots with form 3. The pots were then kept for 48 hours in the incubation chambers. On removal, the pots were placed in a controlled chamber maintained at a temperature of 24°C. and a relative humidity of 75%. Three pots of each set were irradiated, and three were kept as a check. The plants were irradiated in the same manner and for the same length of time as in the last mentioned experiment.

The results of this experiment are presented in Table 36. The rate of teliospore formation in form 3 on the irradiated was identical to that on the check plants, and there was but little difference in the rate of teliospore formation in form 2 on the irradiated and the check plants.

From these experiments it is evident that the rust organism within the plant tissue is not appreciably affected by exposure to ultra-violet light of an intensity which is not lethal or seriously injurious to the host. The results

TABLE 34.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FIVE PHYSIOLOGIC FORMS ON JOANETTE STRAIN IN THE SEEDLING STAGE WHEN IRRADIATED WITH ULTRA-VIOLET LIGHT.

Forms	Types of uredinial infection	
	Produced on check seedlings	Produced on irradiated seedlings
1	3(1) − ; 30 / 35	1(1) − ; 31 / 34
2	33/33(4)	39/39(4)
3	1(1) ; 34 / 35	2(1) ; 33 / 35
4	5(1) ± ; 30 / 35	6(1) ± 2(x) = ; 30 / 33
5	2(1) ± 2(x) = ; 31 / 36	3(1) ± ; 34 / 37

TABLE 35.—THE TYPES OF UREDINIAL INFECTION PRODUCED BY FIVE PHYSIOLOGIC FORMS ON JOANETTE STRAIN IN THE MATURE STAGE WHEN IRRADIATED WITH ULTRA-VIOLET LIGHT.

Forms	Types of uredinial infection	
	Produced on check seedlings	Produced on irradiated seedlings
1	2(1) ± 2(x) = ; 6 / 10	2(1) ± 2(x) = ; 5 / 9
2	10/10(4)c	10/10(4)c
3	2(1) ± ; 8 / 10	2(1) ± ; 9 / 11
4	5(1) ± 1(x) = ; 4 / 10	2(1) ± ; 8 / 10
5	2(1) ± 4(x) = ; 4 / 10	2(1) ± 3(x) − ; 5 / 10

TABLE 36.—DATA CONCERNING THE RATE OF TELIAL DEVELOPMENT OF FORMS 2 AND 3 ON VICTORY IN THE MATURE STAGE WHEN IRRADIATED WITH ULTRA-VIOLET LIGHT.

Forms	Treatments	Number of days				
		From inoculation to first telial development	From inoculation to complete telial development	From first telial to complete telial development	From end of incubation period to first telial development	From end of incubation period to complete telial development
2	Check	14	23	9	6	15
	Irradiated	13	24	11	5	16
3	Chec .	10	16	6	2	8
	Irradiated	10	16	6	2	8

of these experiments are in accord with those of Fulton and Coblenz (*10*) who found that ultra-violet light is unable to penetrate much, if any, below the surface of fruits. Apparently the ultra-violet rays do not penetrate plant tissue to any appreciable distance.

Summary

1. Nine physiologic forms of *P. graminis avenae* were isolated from 1070 collections of oat stem rust in Canada during the six-year period, 1925-1930. These are forms 1, 2, 3, 4, 5, 6, 7, 8 and 9. During 1931, forms 6 and 7, yellow in colour, were isolated from cultures obtained from a barberry which had been artificially inoculated. Of the 1257 isolations made in Canada during the period mentioned, 1213, or 96.5%, consisted of forms 1, 2 and 5.

2. The relation of certain environmental factors, particularly temperature, to the development of the uredinial and telial stages of the various physiologic forms has been studied. The various studies were carried on, with few exceptions, at controlled temperarures within the range 12° to 28°C.

3. It has been shown that the temperature at which the hosts Victory, White Russian, Richland and Joanette Strain are grown prior to inoculation in the seedling stage has no appreciable effect on the types of uredinial infection produced on them later by forms 1, 2, 3, 4 and 5.

4. No significant changes were induced by temperature in the types of uredinial infection produced by forms 2, 6, 7, 8 and 9 on the hosts Victory, White Russian, Richland and Joanette Strain. Similarly, no appreciable differences due to temperature were observed in the types of uredinial infection produced by forms 1, 3, 4 and 5 on the hosts Victory, White Russian and Richland.

5. The types of uredinial infection produced by forms 1, 3, 4 and 5 on the differential host, Joanette Strain, were profoundly changed by temperature.

6. Certain physiologic forms can be distinguished from one another only on Joanette Strain and only when this host is kept at a relatively low temperature (12°C.); when it is kept at a high temperature (28°C.), these particular physiologic forms are indistinguishable. To obviate the necessity of maintaining accurately controlled temperatures while the identification of the physiologic forms present in a large number of collections of oat stem-rust is in progress, the following grouping of the forms, distinguishable only on Joanette Strain at a low temperature, is suggested: Group I, forms 1, 2 and 5; Group II, forms 3 and 7; Group III, forms 4 and 6.

7. Temperature has been shown to be an important factor in the formation of teliospores in *P. graminis avenae*.

8. All the physiologic forms developed teliospores more rapidly on both seedlings and mature plants at relatively high (24° to 28°C.) than at low temperatures (12° to 16°C.).

9. Forms 3, 4, 6, 7, 8 and 9 were found to form teliospores much more rapidly than forms 1, 2 and 5. Since the former group of physiologic forms is more virulent than the latter, a correlation between pathogenicity and rapidity of teliospore formation is indicated.

10. It is suggested that the rarity of forms 3, 4, 6, 7, 8 and 9 in Canada may be due to the early development of telia. Thus the uredinial period is reduced and, as a consequence, the amount of inoculum is greatly diminished.

11. The stage of development of the host was not shown to be a limiting factor in the formation of teliospores by any of the physiologic forms.

12. A high relative humidity (80%) was found to increase both the extent and the rate of telial development on seedlings, while the rate of telial development on mature plants was slightly increased by a low relative humidity (40%).

13. Ultra-violet radiation produced no significant changes in the uredinial or telial development of the physiologic forms.

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THE ECONOMIC SITUATION

PREPARED IN THE AGRICULTURAL ECONOMICS BRANCH DEPARTMENT OF AGRICULTURE OTTAWA FROM BASIC DATA COLLECTED BY THE DOMINION BUREAU OF STATISTICS

Wholesale prices in Canada receded in October. The index number computed by the Dominion Bureau of Statistics was 67.9 as compared with 68.9 in September, a decline of one point. Declines were registered in both the vegetable products and animal products groups. Fibres, textiles and textile products were also lower, whereas wood, wood products and paper, iron and its products and non-metallic minerals were higher. Non-ferrous metals, chemicals and allied products were lower.

Retail Prices.—The total index of retail prices receded from 78.8 in September to 77.9 in October. The food index declined from 65.9 to 65.4. The fuel index rose slightly but the rent index dropped from 84.0 to 80.4. This index is computed in May and October.

Employment.—Employment conditions again showed improvement; the index rose from 86.9 in September to 88.4 in October. The improvement was general except in the Prairie Provinces. The chief gains in employment were in the building trades and in highway construction. Employment increased in mining and logging as well but in manufacturing there was a slight recession.

Physical Volume of Business.—The index of physical volume of business was slightly lower in October when the index was 88.2 as compared with 90.8 in September. Industrial production was also down; the indexes for the respective months were 87.4 and 90.2. Mineral production advanced from 108.8 in September to 117.7 in October. The index of manufacturing moved downward from 97.0 in September to 87.9 in October. Construction increased as did eclctric power production. Car loadings were lower. Both imports and exports were higher.

Agricultural Products.—Prices of Canadian farm products on the whole moved downward in October. The total index fell from 54.7 in September to 51.4 in October. Relatively animal products lost less ground than field products. Declines in the prices of wheat, barley, oats and rye affected the index of prices of field products and this index fell from 49.5 in September to 44.6 in October. In the case of animal products, supplies were not unusually large but the quality was not high and the market weak; the index, therefore, eased down from 63.4 in September to 62.8 in October. The index of agricultural marketings in October declined from 101.1 to 70.5. There was a lower movement of wheat, barley, oats and flax to the head of the lakes and the index of grain marketings fell from 106.2 to 70.0. Live stock marketings were relatively lower than in September. Shipments of cattle were higher, the index advancing from 54.8 to 56.2. The index of marketings of calves dropped from 104.7 to 102.7. The hog index fell from 108.9 to 93.6 and that for sheep from 126.8 to 98.8.

Cold storage holdings were slightly lower, the index moving to 112.7 as at October 1. Supplies of butter, eggs, lard and veal increased whereas stocks of cheese and pork held about even while those of beef, mutton and poultry were lower than in September.

World Trade.—Mr. J. A. MacLeod, General Manager, The Bank of Nova Scotia, discussed the shrinkage of world trade, at the recent Annual Meeting of the Canadian Bankers' Association. He said in part: "Neglecting the statistics of value (which reflect the fall in prices of commodities, that has occurred all over the world, as well as the decline in the volume of transactions), and confining myself entirely to statistics of volume of trade, I find that, since the beginning of the depression, no less than three-eighths of the world's trade has ceased to exist. We are attempting, at present, to carry on with a volume of merchandise trade between the nations of the world, little more than 60 per cent as large as was the volume of trade in the twelve months

ANNUAL AND MONTHLY INDEX NUMBERS OF PRICES AND PRODUCTION COMPUTED BY DOMINION BUREAU OF STATISTICS

Year	Wholesale Prices 1926 = 100				Retail prices and cost of services (5)	Production (6) 1926 = 100			
	All commodities (1)	Farm products (2)	Field products (3)	Animal products (4)		Physical volume of business	Industrial production	Agricultural marketings	Cold Storage holdings
1913....	64.0	62.6	56.4	77.0	65.4	....	....	....	....
1914....	65.5	69.2	64.9	79.0	66.0	....	....	....	....
1915....	70.4	77.7	76.9	79.2	67.3	....	....	....	....
1916....	84.3	89.7	88.4	92.3	72.5	....	....	....	....
1917....	114.3	130.0	134.3	119.6	85.6	....	....	....	....
1918....	127.4	132.9	132.0	134.7	97.4	....	....	....	....
1919....	134.0	145.5	142.4	152.5	107.2	71.3	65.5	48.1	47.1
1920....	155.9	161.6	166.5	149.9	124.2	75.0	69.9	52.6	94.2
1921....	110.0	102.8	100.3	108.5	109.2	66.5	60.4	65.2	86.4
1922....	97.3	86.7	81.3	99.1	100.0	79.1	76.9	82.6	82.6
1923....	98.0	79.8	73.3	95.1	100.0	85.5	83.8	91.4	87.8
1924....	99.4	87.0	82.6	97.2	98.0	84.6	82.4	102.5	114.6
1925....	102.6	100.4	98.1	105.7	99.3	90.9	89.7	97.2	108.9
1926....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1927....	97.7	102.1	99.9	105.7	98.4	106.1	105.6	103.6	110.0
1928....	96.4	100.7	92.6	114.3	98.9	117.3	117.8	146.7	112.8
1929....	95.6	100.8	93.8	112.5	99.9	125.5	127.4	101.1	109.6
1930....	86.6	82.3	70.0	102.9	99.2	109.5	108.0	103.0	128.4
1931....	72.2	56.3	43.6	77.6	89.6	93.5	90.4	99.0	125.7
1932....	66.7	48.4	41.1	60.7	81.4	78.7	74.0	114.3	120.1
1933									
Jan.....	63.9	43.6	35.1	57.9	79.1	68.1	62.2	56.1	112.0
Feb.....	63.6	43.0	36.0	54.7	78.4	67.0	60.9	76.5	127.6
Mar.....	64.4	44.7	38.0	56.0	77.8	68.4	62.5	129.0	135.8
April...	65.4	46.8	41.1	56.4	78.1	69.8	65.1	104.1	112.7
May....	66.9	51.2	46.9	58.4	77.0	76.4	72.7	95.4	100.4
June....	67.6	52.6	49.4	57.9	77.0	82.2	79.8	221.9	119.9
July....	70.5	60.1	60.8	59.0	77.2	84.1	82.6	136.3	114.5
Aug.....	69.4	57.0	54.9	60.5	78.6	89.8	89.5	197.2	114.2
Sept....	68.9	54.7	49.5	63.4	78.2	90.8	90.2	101.1	115.7
Oct.....	67.9	51.4	44.6	62.8	77.9	88.2	87.4	70.5	112.7

1. See Prices and Price Indexes 1913-1928, pp. 19-21, 270-289 and 1913-1931, p. 15.

2. Wholesale prices of Canadian products of farm origin only. See Prices and Price Indexes 1913-1931, p. 33, and Monthly Mimeographs 1932 and 1933.

3. Wholesale prices of grains, fruits and vegetables.

4. Wholesale prices of Animals and Animal Products.

5. Including foods, rents, fuel, clothing and sundries, See Prices and Price Indexes 1913-1928, pp. 181-185, 290-293. 1926 = 100.

Prices and Price Indexes 1913-1931, pp. 122, and Monthly Mimeographs 1932-1933.

6. Monthly Review of Business Statistics, pp. 8, and Monthly Indexes of the Physical volume of business in Canada, supplement to the Monthly Review of Business Statistics, November, 1932.

ending with September, 1929" This information was based upon data from nighteen countries representing about three-quarters of the world's commerce. National self sufficiency has progressed rapidly during the past five years.

Farm Prices in United States.—Indexes published by the Bureau of Agricultural Economics indicate that farm prices held even in October. The index was 70. The index of prices of grains declined 10 points. That of fruits and vegetables dropped from 101 to 86. The index of prices of meat animals advanced from 62 in September to 63 in October. The index of dairy products advanced 2 points and egg prices rose sharply from 77 to 94. The index of prices paid by farmers for commodities purchased remained stationary at 116. These index numbers are constructed on a base period consisting of the five-year average, August 1909 to July 1914 = 100.

The potato crop in United States is reported to be short, amounting to 2½ bushels per capita which is the lowest production recorded in 43 years, and the Bureau of Agricultural Economics anticipated an advance in price. Both the beef cattle and dairy industries are feeling the effect of heavy supplies, but sheep production is tending downward and lambs and wool have enjoyed better prices. Wheat prices in United States though higher than a year ago are still affected by large world stocks, high production and import restrictions in many European Countries.

LA SITUATION ECONOMIQUE

PREPARE PAR LA DIVISION DE L'ECONOMIE AGRICOLE DU MINISTERE DE L'AGRICULTURE, OTTAWA, ET BASE SUR LES DONNEES RECUEILLIES PAR LE BUREAU FEDERAL DE LA STATISTIQUE

Une baisse des prix du gros au Canada s'est produite en octobre. L'indice computé par le Bureau fédéral de la Statistique était de 67.9 contre 68.9 en septembre, soit une diminution de 1 point. Il y a eu diminution également dans les groupes des produits végétaux et des produits animaux. Les fibres, les matières textiles et les produits textiles ont rétrogradé tandis que le bois, les produits du bois et le papier, le fer et ses produits et les minéraux non-métalliques montaient. Les métaux non-ferreux, les produits chimiques et de même nature étaient plus faibles.

Prix de détail.—L'indice total des prix du détail qui était à 78.8 en septembre est tombé à 77.9 en octobre. L'indice des vivres a baissé de 65.9 à 65.4. L'indice du combustible s'est élevé légèrement tandis que l'indice des loyers tombait de 84.0 à 80.4. Cet indice est computé en mai et en octobre.

Embauchage.—Les conditions du travail continuent à s'améliorer. L'indice qui était de 86.9 en septembre est passé à 88.4 en octobre. L'amélioration est générale, sauf dans les Provinces des Prairies. Les industries qui ont fait le plus de progrès sont celles du bâtiment et de la construction des grands chemins. L'embauchage a augmenté dans les industries minière et forestière mais il y a eu une légère rétrogression dans l'industrie manufacturière.

Volume physique des affaires.—L'indice du volume physique des affaires était un peu moins élevé en octobre (88.2 contre 90.8 en septembre). La production industrielle a également fléchi; les indices respectifs pour les mêmes mois étaient les suivants 87.4 et 90.2. Par contre, la production minérale qui était à 108.8 en septembre est montée à 117.7 en octobre. L'indice des produits manufacturés après avoir atteint 97.0 en septembre est tombé à 87.9 en octobre. La construction a progressé, de même que la production d'énergie électrique. Les chargements de wagons étaient moins nombreux. Les importations et les exportations étaient plus élevées.

Produits agricoles.—Les prix des produits agricoles canadiens ont en général baissé en octobre. L'indice total qui était à 54.7 en septembre est tombé à 51.4 en octobre. Les prix des produits animaux ont perdu relativement moins de terrain que ceux des produits des champs. Les baisses qui se sont produites dans les prix du blé, de l'orge, de l'avoine et du seigle ont affecté l'indice des produits des champs, lequel, de 49.5 qu'il était en septembre, est tombé à 44.6 en octobre. En ce qui concerne les produits animaux, les approvisionnements n'étaient pas beaucoup plus abondants que d'habitude mais la qualité laissait à désirer et le marché était faible. C'est pourquoi l'indice est descendu de 63.4 en septembre à 62.8 en octobre. L'indice d'octobre des ventes agricoles est tombé de 101.1 à 70.5. Les transports de blé, d'orge, d'avoine et de lin ont diminué à la tête des Grands Lacs et l'indice des ventes de grain est tombé de 106.2 à 70.0. Les ventes de bestiaux ont été relativement plus faibles qu'en septembre. Les expéditions de bovins étaient plus nombreuses, l'indice passant de 54.8 à 56.2. L'indice des ventes de veaux est tombé de 104.7 à 102.7 celui des porcs de 108.9 à 93.6 et celui des moutons de 126.8 à 98.8.

La quantité de produits entreposés au froid a un peu diminué, l'indice atteignait 112.7 au 1er octobre. Les approvisionnements de beurre, d'oeufs, de saindoux et de veau ont augmenté tandis que les stocks de fromage et de porc restaient à peu près stationnaires et que ceux de boeuf, de mouton et de volailles étaient inférieurs à ceux de septembre.

Le commerce mondial.—A la dernière réunion annuelle de l'Association des Banquiers canadiens, M. J. A. MacLeod, Gérant Général de la Banque de la Nouvelle Ecosse, a parlé du ralentissement du commerce mondial et a dit à ce sujet: "Laissant de côté la statistique de la valeur (qui réflète la baisse qui s'est produite dans les prix des marchandises dans le monde entier ainsi que la diminution du volume des stocks) et ne prenant que la statistique du volume du commerce, je trouve que depuis le commencement de la dépression les trois huitièmes au moins du commerce mondial ont disparu. Le commerce des marchandises qui se fait actuellement entre les nations du monde n'est guère plus de 60 p.c. de ce qu'il était dans les douze mois qui ont suivi septembre 1929." Ces renseignements sont basés sur les données fournies par dix-neuf pays, représentant les trois quarts du commerce du monde. En ces cinq dernières années les nations ont fait un grand progrès dans l'art de se suffire à elles-mêmes.

Les prix de la ferme aux Etats-Unis.—Les indices publiés par le Bureau de l'Economie agricole indiquent que les prix de la ferme se sont maintenus en octobre. L'indice est à 70. L'indice des prix des grains a baissé de 10 points. Celui des fruits et des légumes a baissé de 101 à 86. L'indice des prix des animaux à viande est passé de 62 en septembre à 63 en octobre. L'indice des produits laitiers est monté de 2 points. Celui des oeufs s'est élevé brusquement de 77 à 94. L'indice des prix payés par les cultivateurs pour les produits qu'ils achètent est resté stationnaire, à 116. Ces chiffres indices sont calculés sur une période de base, dans laquelle a moyenne de cinq ans, août 1909 à juillet 1914, est representée par le chiffre 100.

Aux Etats-Unis la récolte de pommes de terre est déficitaire, se montant à 2½ boisseaux par tête; c'est la plus faible production que l'on ait enregistrée depuis 43 ans, et le Bureau de l'Economie agricole prédit une hausse de prix. L'élevage des boeufs de boucherie et l'industrie laitière se ressentent des approvisionnements abondants, mais la production du mouton est en baisse et les prix des agneaux et de la laine ont remonté. Les prix du blé aux Etats-Unis, quoique un peu plus élevés que l'année dernière, sont encore affectés par les gros stocks mondiaux, les fortes productions et les restrictions imposées par beaucoup de pays européens importateurs.

RESUME DES ARTICLES PUBLIES EN ANGLAIS DANS CE NUMERO

La Relation des Services Agricoles aux Conditions Variantes. Sir E. John Russell, Directeur de la Station agronomique de Rothamsted, Harpenden, Herts, Angleterre.

On donne un exposé des changements survenus dans l'agriculture qui ont rendu nécessaire en Angleterre l'adoption d'un système réparti d'importation de denrées alimentaires. On appuie sur le besoin de recherches scientifiques pour l'extension de l'agriculture, particulièrement aù l'on fait de la culture spécialisée, étant donné que le spécialiste est plus exposé à perdre ses revenus que le cultivateur ordinaire. Il est déclaré que les produits canadiens les plus recherches en Angleterre sont le blé, le fromage et les pommes.

Quelques Aspects des Marches D'Outremer pur le Miel Canadien. J. K. Galbraith, Université de la Californie, Berkeley, Cal.

L'Allemagne et le Royaume-Uni sont les deux principaux pays importateurs. Les perspectives pour le miel canadien sur le marché allemand ne sont pas favorables s'il s'agit d'une période limitée, mais sont meilleures s'il s'agit d'une période plus

longue. Sur le marché britannique le Canada occupe une position relativement favorable. Le maintien de cette position requierera cependant la poursuite d'un système progressif de ventes.

ETUDES ABREGEES SUR LA BACILLE CALMETTE-GUERIN (B.C.G.) ET LA VACCINATION CONTRE LA TUBERCULOSE. E. A. Watson, Institut de recherches sur les maladies animales, Hull, P.Q.

L'on a trouvé que le vaccin B.C.G. ne protégeait pas le bétail contre la tuberculose, quoique au cours de leurs premieres années, a tuberculose se développait d'une façon plus lente chez les animaux vaccinés, indiquant ainsi un certain degré de résistance.

UNE ETUDE DU RAPPORT DE L'ENVIRONNEMENT SUR LE DEVELOPPEMENT DES PHASES UREDINIALES ET TELIALES DES FORMES PHYSIOLOGIQUES DE *Puccinia Graminis Avenae* ERIKKS. ET HENN. W. L. Gordon, Dominion Rust Research Laboratory, Winnipeg, Man.

Comme cette étude couvre beaucoup de recherches sur le développement des spores en rapport avec les rouilles sur l'avoine, il ne nous est pas possible d'en donner ici un bref résumé.

UN MESSAGE DE SIR JOHN RUSSELL

A mes Collègues Canadiens-Français.

Il m'est difficile de vous exprimer le grand plaisir que j'ai éprouvé à visiter la belle province de Québec. L'invitation de M le Ministre d'agriculture, le Dr Godbout, et la bonté de mon viel ami le Dr Archibald, m'ont permis de réaliser le désir que j'avais de la voir. Avant mon voyage je savais bien des choses sur cette province: j'avais lu, comme tout le monde, le beau roman de Louis Hémon et les livres de Georges Bouchard, ces esquisses de la vie canadienne-francaise qui donnent une vision pleine d'attrait. Mais, voir les choses actuelles—les villages, les manoirs anciens, les églises aux clochers si charactéristiques et aux flèches si élégantes—et, surtout m'entretenir avec les habitants, ce fut un plaisir inexprimable. A la joie de visiter Québec s'ajoutait le plaisir d'entendre parler encore une fois la langue française—cette belle langue qui sonne si douce à nos oreilles!

L'histoire de Québec est une grande épopée! Les aventures des voyageurs, la hardiesse et le travail des habitants, leur ont gagné l'admiration vive de tout le monde. C'est une histoire de courage glorieux, de grandes souffrances et de plus grande résist ance, finalement de la victoire humaine—la puissance conquérante du soc maîtrisant la forêt sauvage, et la transformant en un pays hospitalier, un paysage souriant, riche en villages et fermes et bon pour l'homme et le bétail.

Ces qualités qui ont permis un si grand accomplissement dérivent du présent et du passé. Vos devanciers ont apporté ici quelque chose de la civilisation de la France du dix-septième et du dix-huitième siècle: quelque chose que la vie dure a purifié et transformé en une vie plus simple, plus naturelle que celle des cités d'aujourd'hui. Gardez-la! Gardez les plus nobles traditions de votre race, et la fraîcheur de l'âme française, et souvenez-vous toujours des paroles de Rodolphe Lemieux: "La terre, source de nos richesses, espoir de notre avenir, non seulement fait germer la moisson, mais contribue à l'épanouissement des plus solides vertus de la race".

Non seulement faut-il conserver la meilleure partie de la vie ancienne: il faut y ajouter la meilleure partie de la vie moderne. Travaillez-donc toujours, afin que vous puissiez alléger le fardeau des souffrances et des détresses d'aujourd'hui et que vous puissiez contribuer à la richesse et à l'allégresse de la vie de demain.

E. J. RUSSELL.

Directeur de la Station agronomique de Rothamsted,
Harpenden, Angleterre.

NOTES AND NEWS

The difficulties of maintaining a balance of interest in the contents of *Scientific Agriculture* from month to month are by no means small. This month we find our page arrangements working out in such a way that only two pages are left for news items. As we ran nine pages last month, and expect to have room for five or six in January, we hope the lapse in this issue will be overlooked.

Attention is directed to the address in this issue by Sir John Russell. It should be read in connection with the address by Sir Daniel Hall, published in the October issue. The Editor, during a recent trip to the Royal Fair, was disappointed to find that many had not read the article by Sir Daniel, and, in fact, confessed that they "had not had time" to read any of the last three issues. While we are willing to admit that in previous volumes there may have been a lack of readable material in many of the numbers, we want to remind members now that each issue of *Scientific Agriculture* contains at least one article which should be read by every member. We are making a definite effort to develop the official organ of the C.S.T.A. into a journal more representative of the Society, and as such a definite factor in the shaping of Canadian agricultural policy. This does not involve any alteration of the policy of the journal in publishing research contributions; it involves a more extensive use of economic material and the inclusion of articles on administrative policy by such outstanding authorities as we may be able to secure from time to time, and by our own members who are especially qualified to speak along this line. In this connection we would refer to the two papers on horticultural research methods in Great Britain by Mr. R. C. Palmer of Summerland in the November issue, and to a paper on animal research methods in Great Britain by Dr. R. D. Sinclair of Edmonton which will appear in January.

Following a policy adopted two years ago whereby the institution concerned pays for extra space, we have accepted an occasional long article of the type of Mr. W. L. Gordon's in this issue. This paper represents an outstanding contribution in the field of plant pathology. In cases where a research project involves a point of immediate interest in agricultural practice, we hope to follow the recommendations of previous C.S.T.A. conventions and present the material in condensed form. In this connection we have published in this issue an enlargement of the abstract of a paper published in the *Canadian Journal of Research* on the vaccination of cattle for the prevention of tuberculosis. The results obtained in this work are of vital interest to all engaged in animal husbandry, and should be of general interest to all technical agriculturists. Dr. Watson's courtesy in preparing a special statement on this subject for readers of *Scientific Agriculture* is greatly appreciated.

ANNUAL C.S.T.A.–O.A.C. ALUMNI BANQUET

The annual joint banquet held at the time of the Royal Winter Fair under the auspices of the Central Ontario branch of the C.S.T.A. and the Ontario O.A.C. Alumni Association seems to have become a permanent institution. The committee of management is always able to count on an attendance of about one hundred and fifty members and graduates. With Paul Fisher of Burlington, President of the Alumni Association, in the chair, and Dean Howes of Edmonton, former President and one might say "Dean" of the C.S.T.A., as guest speaker, the success of the programme was assured. Some ten or twelve additional speakers failed to satisfy the demand for reminiscences, and the crowd did not disappear from the corridors for over an hour after the programme had been officially brought to a close.

Hon. T. L. Kennedy, Minister of Agriculture for Ontario, was guest of honour, and Dr. L. Ph. Roy represented Hon. Adelard Godbout, Minister of Agriculture for Quebec and President of the C.S.T.A., who was unable to be present.

F. W. WALSH JOINS NOVA SCOTIA DEPARTMENT

Announcement has recently been made that F. Waldo Walsh, Agricultural Superintendent, Canadian National Railways, Montreal, has joined the Nova Scotia Department of Agriculture at Halifax to direct marketing activities. Mr. Walsh is a native of New Brunswick although a considerable part of his early life was spent in Nova Scotia. He graduated from the N.S.A.C. and went to Guelph where he received his B.S.A. in 1922. As a member of the O.A.C. Stock Judging Team, he was high man at the International Show at Chicago. Following graduation he was in the employ of the New Brunswick Department of Agriculture, becoming Live Stock Superintendent, and later was on the staff of the Dominion Live Stock Branch with headquarters at Truro, where he was active in promoting co-operative marketing. Subsequently he joined the staff of the N.S.A.C. as instructor in animal husbandry, resigning this position to become Maritime Agricultural Superintendent of the Canadian National Railways.

Mr. Walsh is well fitted to take up the work of promoting agricultural marketing activities in Nova Scotia. On account of his wide experience and his close personal contacts with men in all fields of agricultural services in Canada, he will undoubtedly be called upon to advise the Department along many lines. He has a background of practical farm training and is a hard worker and straight thinker. The Nova Scotia Department of Agriculture has made great progress in developing its service to the farmers in the province, and it is expected that in the field of marketing further valuable services will be rendered under the leadership of Mr. Walsh.

ACTIVITIES OF THE MANITOBA BRANCH

The action of the Manitoba branch of the C.S.T.A. in organizing study groups for the winter months is to be highly commended. Under the leadership of the executive, headed by Mr. H. E. Wood of the Manitoba Department of Agriculture, four study groups have been organized as follows: Live Stock Problems Group, T. P. Devlin—Chairman, L. Hancock—Secretary; Agricultural Economics Group, R. D. Colquette—Chairman, George Batho—Secretary; Grain Problems Group, T. J. Harrison—Chairman, J. A. McGregor—Secretary; Dairy Problems Group, K. G. MacKay—Chairman, J. McLean—Secretary. Each of these groups has laid out a programme of papers, and an increasing amount of interest is developing. The last letter from the Secretary of the branch, Mr. J. R. Sweeney, Dominion Dairy Branch, Winnipeg, enclosed reinstatements for two members and applications for six new members, and a request for more application forms. This is the spirit which is needed at this particular time.

NEWS ITEMS

S. W. Edgecombe (Manitoba '29) is now with the Emergency Conservation work under the United States Forest Service in the capacity of Forest Pathologist and is located at McGregor, Iowa.

D. B. Flewelling (McGill '12) is now agent for Bell and Sons of Exeter, England, handling veterinary medicines and mineral mixtures for live stock. The head office of the company is in Montreal and Mr. Flewelling is located at Bridgewater, N.S.

Hector Béliveau (Laval '26) has been appointed to the staff of the new School of Agriculture at Ste. Martine, Chateauguay County, P.Q.

M. S. Middleton, (Toronto '09) of Vernon, B.C., recently won first prize for rye at the International Show at Chicago. As Mr. Middleton was also first at the World's Grain Exhibition and Conference at Regina, he would seem to have won the undisputed title of "Rye King".

M. A. Collins (Saskatchewan '28) has moved to Toronto where he is in the employ of the Dairy Corporation of Canada, 80 King Street West.

W. S. Nesbitt (Manitoba '31) has changed his address to St. Lazare, Man.